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PROCEEDINGS
OF THE
ROYAL SOCIETY OF VICTORIA

NEW SERIES
VOLUME 81

ROYAL SOCIETY'S HALL
9 VICTORIA STREET, MELBOURNE, 3000

1968

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THE EFFECTS OF SALT SPRAY ON COASTAL VEGETATION AT WILSON'S PROMONTORY, VICTORIA, AUSTRALIA

By R. F. PARSONS* and A. M. GILL†

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Abstract

The vegetation of a coastal area exposed to strong winds carrying salt spray was investigated. Severe leaf-tip necrosis and the death of seaward shoots were found to be of widespread occurrence. Detailed studies of the succulence, salt content and internal morphology of leaves both from areas exposed to salt spray and from sheltered areas were made. These suggest that chloride toxicity caused by salt spray is a major factor determining the occurrence and growth of plants in exposed coastal areas.

Introduction

Salt spray as an ecological factor has received scant attention in Australia. Wood (1937) notes the occurrence of the halophytes *Disphyma australe* and *Suaeda maritima* on cliffs exposed to salt spray in South Australia, and similarly Willis (1962) in Victoria notes *D. australe* and *Salicornia australis* 'on littoral platforms and spray drenched ledges of rock'. The prevalence of succulent plants on exposed coastlines in general is well known (Smith 1957, Gillham 1960), and Smith (1957) notes that *Senecio laetus* becomes more succulent the nearer it grows to the sea. However, no reasons are suggested for this phenomenon.

Various adverse effects on the growth of shrubs on exposed coastlines have been observed. For example in Australia Pidgeon (1937) has noticed stunting of coastal shrubs, and attributed this to exposure to wind, without considering the precise mechanisms involved. Smith (1957) noticed stunting, and also the inhibition of seaward growth on coastal shrubs, and Osborn (1922) noted dead areas on the seaward sides of coastal shrubs; these phenomena were ascribed to 'wind pruning' or 'wind shearing' which presumably implies mechanical breakage of stems and leaves by wind.

Elsewhere the effect of salt spray on vegetation is well documented (Boyce 1954, Karschon 1958). It is the aim of this paper to describe the effect of salt spray on coastal vegetation near Tidal R., Wilson's Promontory.

The Study Area

Wilson's Promontory is the southernmost part of mainland Australia. The study area was located on its exposed W. coastline at Pillar Point, half a mile NE. of Tidal R. Pillar Point is a NE.-SW. trending granitic ridge, its NW. side (the study area) forming part of Leonard Bay, and its SE. side forming part of Norman Bay.

The field work was undertaken in September 1964 and June 1965 as part of the ecology practical work for Botany II, Botany IIA and Agricultural Botany II students of those years (University of Melbourne).

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The General Environment

The study area is adjacent to the area of vegetation mapped by Parsons (1966), and he has presented the relevant general climatic data. In brief the climate is maritime, with a mean annual rainfall of 43 in. The monthly prevailing wind direction is W. for all months except July (NW.), August (NW. and W.) and December (W. and NE.). Mean monthly wind speeds at 9 a.m. show no marked seasonal trends and vary from 13 to 18 miles per hour. Consequently the NW. side of Pillar Point is exposed to onshore winds, often of high speed, throughout the year, while its SE. side is much more sheltered.

Onshore winds were frequently observed to carry salt spray from the surface of the sea inland over the entire NW. side of Pillar Point.

The soils of the area are extremely variable. Parts of the lower slopes of the NW. side of Pillar Point have received an accession of wind-blown siliceous sand. Elsewhere the soils are derived from granite; they are often very shallow, and large outcrops of granite are common. Parsons (1966) has described the granitic soils of adjacent areas.

Vegetation

The vegetation of the NW. side of Pillar Point varies more or less continuously from the shoreline to the top of the ridge. However, at least four zones are readily discernible.

(1) Immediately behind the shoreline, pockets of shallow, poorly drained peaty soils occur on flat expanses of granite, around and between granite boulders, and near salt water rock-pools. The area regularly comes under the influence of wave splash, especially during conditions of high tides and strong onshore winds. The soil pockets carry a community of herbaceous perennials, many of which also occur in the salt marsh at the mouth of Tidal R. The principal species are *Cladium junceum*, *Samolus repens*, *Hydrocotyle muscosa*, *Disphyma australe*, *Leptocarpus brownii*, *Viola hederacea*, *Stipa teretifolia* and *Carex* sp. This community has not been investigated in detail here because it is almost certainly subject not only to a large amount of salt spray, but also to high levels of soluble soil salts due to a combination of wave splash and poor drainage.

(2) Leeward from zone (1), above the main wave-splash zone, on well-drained siliceous sands and shallow granitic soils, there is a narrow and rather discontinuous 'zone' in which the following plants are common: *Calocephalus brownii*, *Correa alba*, *Alyxia buxifolia*, *Helichrysum gunnii*, *Persoonia juniperina*, *Grevillea lanigera*, *Banksia integrifolia*, *Tetragonia implexicoma*, *Helichrysum apiculatum*, *Scirpus nodosus*, *Leptospermum juniperinum*, *Pultenaea daphnoides*, *Senecio lantus*, and *S. elegans*. *Calocephalus brownii* forms a conspicuous fringe along the seaward edge of this zone, as it does elsewhere (Osborn 1922). Dense mats of prostrate *Goodenia ovata* occur in wet areas which appear to receive freshwater seepage from the higher parts of Pillar Point. These mats may also be subject to occasional wave splash.

(3) Further upslope, zone (2) is replaced by a heath (Wood & Williams 1960) dominated by *Leptospermum laevigatum*. *Leucopogon parviflorus* and *Casuarina stricta* are also common, and *Banksia integrifolia* and *Kunzea ambigua* occur occasionally. This zone occurs mainly on siliceous sands.

(4) On the upper half of the NW. side of Pillar Point the soils are mainly granitic, *Leucopogon parviflorus* disappears, and a number of species from *Casuarina pusilla*-*Leptospermum myrsinoides* heath (Parsons 1966) occur in the

L. laevigatum heath, including *Epacris impressa*, *Correa reflexa* and *Lepidosperma concavum*. At the NE. (landward) end of this highest zone, *Eucalyptus radiata* and *E. baxteri* occur as shrubs up to 10 ft high.

In zones (3) and (4), *Casuarina stricta* and *Kunzea ambigua* replace *L. laevigatum* heath on shallow soils around granite outcrops.

In contrast to these low-growing heath communities on the NW. side of Pillar Point, the SE. side carries a *L. laevigatum* thicket 15 ft high, as well as some other taller communities (Parsons 1966).

Growth Forms

Most of the shrubs growing along the seaward edge of zone (2) showed a strikingly asymmetric growth form. Branch development is much greater on the landward side of the shrubs than on the seaward side, and the canopy slopes up evenly from the seaward side, beginning at ground level and reaching heights of up to 6 ft on the landward side (Plate 1). Most of the shrubs are stunted compared to the size they attain in sheltered locations, and the main branches are usually curved in the shape of an arc pointing landward, and are more or less prostrate (Plate 1). Plan diagrams of shrubs growing in the most open parts of the community showed that these shrubs were markedly elliptical, the long axis of the ellipse running at right angles to the shoreline; in these cases growth is inhibited in all directions except directly landward.

This asymmetric growth form was observed in all the shrub and tree species on the exposed NW. side of Pillar Point. However, in more sheltered inland areas, plants of these species showed normal, symmetrical development. The same asymmetric growth forms occur in a wide range of exposed coastal areas (Boyce 1954). Several hypotheses have been advanced to explain the different rates of growth on the seaward and landward sides of plants and these have been reviewed to Boyce (1954). The most common hypotheses are:

(1) **Sandblasting.** Boyce (1954) observed some sandblasting damage to stems near ground level, but produced evidence that sand is not transported at sufficient height to cause asymmetric growth forms. At Pillar Point, the shoreline is granitic, and the areas of sand stabilized, so sandblasting is unlikely.

(2) **Desiccation** of seaward shoots and leaves by wind. At Pillar Point, no signs of wilting were observed. Although it appears that desiccation cannot cause asymmetric growth forms (Boyce 1954), exposure to wind may contribute to the general stunting of coastal plants by causing increased evapotranspiration or by causing stomatal closure and lowered photosynthesis.

(3) **Mechanical breakage by wind.** It was not possible to evaluate this hypothesis in the study area because of damage caused by tourists. However, other work indicates that in wind regimes like those of the study area, it is generally unimportant (Boyce 1954, Warren Wilson 1959), while in areas subject to hurricanes, mechanical breakage occurs but does not produce asymmetric growth forms (Boyce 1954).

(4) **Salt spray.** In the study area, the asymmetric growth forms were invariably accompanied by severe leaf-tip necrosis of seaward leaves; judging from the critical studies of Boyce (1954), it would appear that toxic amounts of chloride ions from salt spray were being deposited on the vegetation, inhibiting seaward growth and producing the asymmetric growth forms. This hypothesis was supported by observations of salt spray being carried by wind over the entire NW. side of Pillar Point, and by observations of numerous salt crystals on exposed leaves and stems in dry weather.

In addition to asymmetry and leaf-tip necrosis, large areas of dead shoots were present on the seaward sides of many shrubs. Also, many dead shoots protruded a few inches above the living canopy on the seaward side of these shrubs. The nearest leaves to these dead areas almost invariably showed leaf-tip necrosis, suggesting a common cause for the death of both shoots and leaf tips. Again, the work of Boyce (1954) has shown that such symptoms may be caused by chloride toxicity.

Leaf Morphology and Salt Content

As soluble salts in either soils or salt spray are known to enter plants and induce succulence (Boyce 1954), the morphology and salt content of a number of species were investigated in detail.

METHODS

Leaf thickness was measured with a dial micrometer calibrated in divisions of 0.001 in.

Estimates of total soluble leaf salts were obtained from a conductance bridge (Jackson 1962). For this analysis 15 g. fresh weight of leaves were shaken in two changes of 100 ml. of distilled water for one min. each change on a 'Microid' flask shaker, to wash off salts present on the leaf surfaces. The final leaf washings did not contain detectable amounts of salts. The leaves were then ground up for two min. in 75 ml. of distilled water, using a 'Waring Blendor'. This suspension was filtered (Whatman No. 1 filter paper), the filtrate drawn up into a conductance cell, and its conductance measured on the conductance bridge.

INVESTIGATIONS

As a first step, the morphology and salt content of leaves of plants growing in the salt spray-exposed area were compared with those of leaves of plants of the same species from areas sheltered from salt spray, to see if any differences in succulence or salt content were present between them. Leaf succulence was measured as the thickness : area ratio, fresh weight : dry weight ratio and/or the fresh weight : area ratio.

Leaves were sampled from exposed shoots in comparable light regimes at the tops of the plants at both sites. Each population of leaves was then sorted into five

TABLE 1

Fresh weight : dry weight ratios, and conductance of leaf extracts of plants exposed to salt spray and of plants from areas sheltered from salt spray
All ratios are means of 50 leaves from 5 area classes

Species	Location			
	NW. side of Pillar Point (salt spray area)		Various locations sheltered from salt spray	
	Fresh weight : dry weight	Conductance (mhos x 10 ⁶)	Fresh weight : dry weight	Conductance (mhos x 10 ⁶)
<i>Goodenia ovata</i>	8.45	192	3.72	< 9
<i>Correa alba</i>	4.47		2.99	
<i>Myoporum insulare</i>	11.72	833	5.94	500
<i>Pultenaea daphnoides</i>		169		< 9
<i>Eucalyptus radiata</i>		147		109
<i>Leptospermum laevigatum</i>	2.39	250	2.54	143

area classes, each of ten leaves, and mean leaf thickness, fresh weight and dry weight obtained.

Leaf thickness and fresh weight measurements showed that the salt spray populations of *Goodenia ovata*, *Correa alba*, *Myoporum insulare* and *Pultenaea daphnoides* had thicker leaves in all area classes and higher fresh weights per unit

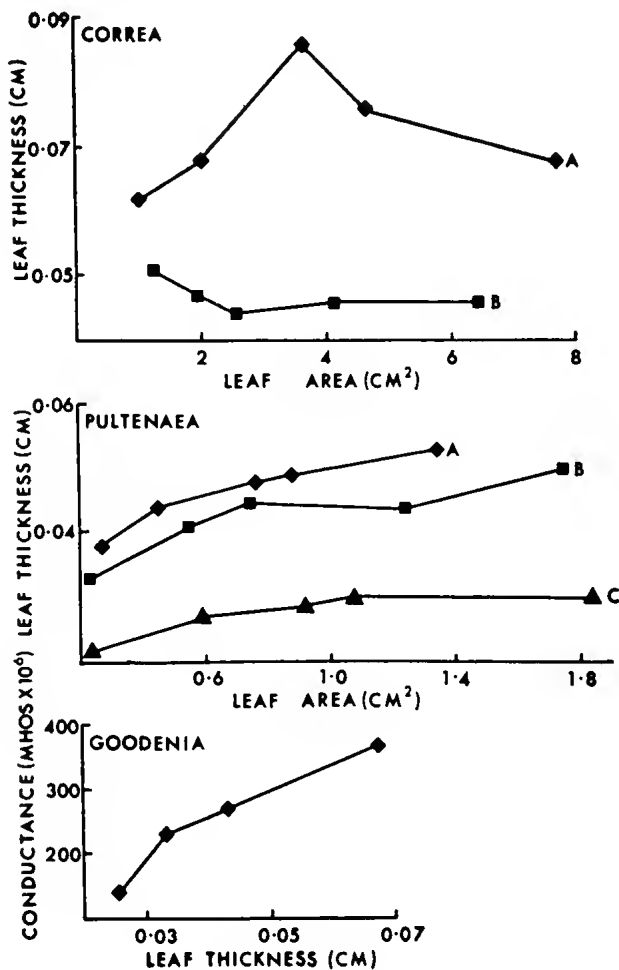


FIG. 1

Top: the relationship between leaf thickness and leaf area for leaves from the seaward side (graph A) and landward side (graph B) of a single shrub of *Correa alba* exposed to salt spray.

Middle: the relationship between leaf thickness and leaf area for three populations of *Pultenaea daphnoides*.

Graph A—Top of Pillar Point.

Graph B—Seaward edge of Pillar Point.

Graph C—Inland location sheltered from salt spray.

Bottom: the relationship between conductance of leaf extract and leaf thickness for leaves of *Goodenia ovata*.

area than the sheltered populations (Fig. 1). In addition, the salt spray populations of the three of these species tested had larger fresh weight : dry weight ratios (Table 1). The salt spray populations of all four species were more succulent than the sheltered populations in every comparison made with these three indices of succulence. Also, *Grevillea lanigera* and *Senecio lautus* were shown to have thicker leaves in all area classes in the salt spray area than in sheltered areas. By contrast, comparisons of populations of *Leptospermum laevigatum* using all three indices showed that this species does not become detectably more succulent in the salt spray area. However, the salt analyses showed that the leaves of the salt spray populations of every species examined contained higher concentrations of salts than those of the sheltered populations. (Table 1.)

These observations showed that the development of succulence was accompanied by high salt content. To try to relate succulence to salt content more closely, leaves of *Goodenia ovata* were divided into four thickness classes, and the salt content of each class was obtained. In this species, increasing thickness was accompanied by increasing salt concentration (Fig. 1), further indicating the causal relationship between salt content and succulence shown by Boyce (1954).

In an attempt to relate the observed succulence specifically to air-borne salts, leaves were collected from the seaward and landward sides of the outer canopy of an open grown shrub of *Correa alba*, and their weight, area, thickness and salt content determined as before. Leaf thickness, fresh weight and conductance were all consistently higher for the leaves from the seaward side of the shrub (Table 2;

TABLE 2

Fresh weight : dry weight ratios and conductance of leaf extracts of leaves from the seaward and leeward sides of a single plant of Correa alba from the salt spray area

All ratios are means of 50 leaves from 5 area classes

	Fresh weight: dry weight	Conductance (mhos x 10 ⁶)
Seaward side of shrub	5.10	555
Leeward side of shrub	3.56	172

Fig. 1). This phenomenon is referred to as diamorphic succulence by Boyce (1954). The landward leaves were closely comparable in succulence with the leaves from the sheltered inland population analyzed earlier, showing that the succulence and high salt contents of leaves from the salt spray area are caused principally by air-borne salts, and that soil salts, which would produce equal succulence on seaward and landward leaves, were of less significance. Unpublished chloride analyses by Dr. D. H. Ashton and students have since shown for a number of the species investigated here, that leaves from salt spray populations contain higher chloride concentrations than leaves from sheltered populations, and also that seaward leaves of *Correa alba* contain higher chloride concentrations than leeward leaves from the same shrub.

Field observations had shown that asymmetric growth forms and leaf-tip necrosis of seaward leaves occurred over the entire NW. side of Pillar Point, suggesting that chloride toxicity from salt spray occurred over this entire area. This hypothesis was tested by sampling leaves of *Pultenaea daphnoides* simultaneously from the seaward edge of the shrub zone, from the top of Pillar Point, and from an inland location sheltered from salt spray. Succulence and salt content

were closely comparable for the two Pillar Point populations, and much lower for the inland population, suggesting that salt spray is deposited over the entire NW. side of Pillar Point. In addition, leaves of *Eucalyptus radiata* from the landward edge of zone (4) showed typical chloride toxicity symptoms (Karschon 1958), and higher salt content than leaves from sheltered inland areas (Table 1).

The succulence of plants from the salt spray area was further investigated by microscopic inspection of transverse sections of leaves both from the salt spray area and from areas sheltered from salt spray. The species investigated were *Senecio laetus*, *Goodenia ovata*, *Correa alba* and *Grevillea lanigera*. Measurements of cell size with a micrometer eye-piece showed that in all these species, the increased succulence of the salt spray populations was caused by the hypertrophy of palisade and spongy mesophyll cells. In some cases, palisade cells were twice as long in leaves exposed to salt spray as in leaves sheltered from salt spray. Such hypertrophy is usually assumed to be a dilution phenomenon, i.e. an increased water uptake by the cell in response to a high concentration of salts derived from salt spray deposition (Boyce 1954). The thicker leaves of the salt spray populations of the species studied showed no evidence of any increase in the number of cell layers forming the lamina, in agreement with other work (Boyce 1954).

Discussion

The work described here and previous work (Boyce 1954, Karschon 1958) demonstrates that salt spray is a major factor determining the occurrence and growth of plants in exposed coastal areas. The most important effect of salt spray on vegetation is the deposition of large amounts of salt on aerial plant parts, frequently causing the death of shoots and leaves from chloride toxicity. The exposed coastal environment thus shows an important similarity to the salt marsh environment, where high concentrations of soil chloride are an important feature of the habitat. As a consequence, salt marsh plants like *Samolus repens* and *Disphyma australe*, which are adapted to high levels of soil chloride, occur also in badly drained parts of salt spray areas where they are subjected to high concentrations of chloride in both soil and air. However, large parts of salt spray areas differ from salt-marshes in having well-drained soils, so that they are not so closely related to them floristically. Nevertheless, at Pillar Point, two species from well-drained areas subjected to salt spray are also known from areas not subjected to salt spray but to high concentrations of soil chloride. These species are *Myoporum insulare*, which Parsons (1966) records from sheltered areas subjected to tidal inundation at Tidal R., and *Calocephalus brownii* which occurs 'in salt country inland' (Black 1957).

There appears to be a wide diversity of adaptations to air-borne salts in the salt spray community. *Calocephalus brownii* grows nearer to the sea than any of the other shrubs present in the area and very rarely shows any salt spray damage; it may therefore be the shrub most resistant to salt spray. The shoot system of this non-succulent species is densely branched, compact and hemispherical, and thus it is a typical cushion plant. Unlike the other shrubs in the area, it does not develop asymmetrically, except in the most severely exposed sites. The cushion habit of this plant presents a streamlined surface to wind and wind-borne salts. In addition, the shoots of *C. brownii* are completely covered by a fine white tomentum which may prevent salt spray from penetrating into leaves and stems. *Grevillea lanigera* is another species covered with fine hairs. Like *C. brownii*, it is practically confined to areas exposed to large amounts of salt spray. Another shrub, *Casuarina stricta*, has slender switch-like cladodes which readily align themselves parallel to the wind

and in this way the area of shoot surface exposed to both wind and salt spray is greatly reduced.

The dominant shrub in most of the salt spray area is the sclerophyllous *Leptospermum laevigatum*. The present work has shown that this species does not develop detectable succulence in response to airborne salts. The work of Patton (1934) has shown that leaves of this species possess a very thick cuticle. This feature may lead to a reduced rate of entry of air-borne salts into leaves, and help to account for the presence of this species in salt spray areas, as suggested by Boyce (1954) for some non-succulent dune grasses of low salt content. The salt spray populations of the remainder of the species investigated were all more succulent than the populations from areas sheltered from salt spray. This difference in succulence was shown to be principally phenotypic in the case of *Correa alba*, in which marked diamorphic succulence was demonstrated. Such phenotypic variation caused directly by varying amounts of salt spray may also account for the observations by Smith (1957) and the present authors that *Senecio lautus* becomes more succulent the nearer it grows to the sea, and for similar differences in succulence for the other species investigated here. However the possibility of the development of 'salt spray ecotypes' within these species, like that found by Boyce (1954), cannot be discounted.

Eucalypts are absent from the salt spray area except at its most inland margin, where some scattered shrubs of *E. radiata* occur. These plants show an asymmetric growth form (Plate 1), a higher leaf salt content than sheltered inland plants (Table 1), and identical symptoms to those of other eucalypts of severe air-borne salt damage (Karschon 1958). It appears that the eucalypts occurring adjacent to the study area (Parsons 1966) are intolerant of salt spray, and that this factor excludes them from exposed coastal locations.

Previous Australian work attributing the asymmetric growth forms and smooth sloping crowns of exposed coastal shrubs to 'wind-pruning' and 'wind-shearing' (Osborn 1922, Smith 1957) now appears to be in error. In the present study, the close association of dead shoots with leaves showing chloride toxicity symptoms and having high salt content, strongly suggests that chloride toxicity is the cause of the characteristic growth forms of exposed coastal shrubs. This hypothesis is supported both by the previous work of Boyce (1954) on the role of air-borne salts in causing leaf and shoot death and subsequently asymmetric growth forms, and by the work cited in Boyce (1954) and Warren Wilson (1959) indicating that wind speeds in the study area would not be sufficient for any significant amount of mechanical breakage.

Acknowledgements

The work described formed a student project for second year Botany students at the University of Melbourne in 1964 and 1965. Their enthusiasm and interest is gratefully acknowledged. We also wish to thank Dr. D. H. Ashton, who suggested the project, and critically read the manuscript.

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Explanation of Plate

PLATE 1

- Top: Portion of the vegetation on the NW. side of Pillar Point. The coastline is approximately one chain directly to the right of the photograph. Two shrubs of *Leptospermum laevigatum* showing asymmetric growth forms are on the left; the one in the foreground also shows a large area of dead shoots on its seaward side. On the right are shrubs of *Calocephalus brownii* showing the cushion habit.
- Middle: A small prostrate shrub of *Leptospermum laevigatum* on the NW. side of Pillar Point, showing a curved stem and dead seaward shoots. The ruler is one foot long.
- Bottom: A shrub of *Eucalyptus radiata* on the top of Pillar Point showing dead seaward shoots and leaf tip necrosis of seaward leaves. *Kunzea ambigua* on the left of the photograph.



ON *CYATHOPHYLLUM MANSFIELDENSE* DUN 1898: LOWER DEVONIAN, LOYOLA, VICTORIA

By D. L. STRUSZ

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Abstract

This revision is based on original material from the George Sweet Collection of the National Museum of Victoria; the specimen figured by Dun is chosen lectotype. The species, which is solitary or possibly weakly colonial, is considered to belong to *Acanthophyllum* (*Neostriophyllum*) *sensu* Birenheide. The corallite wall is shown to consist of the expanded bases of lath-like septal trabeculae, without the addition of lamellar sclerenchyme.

The species is known from the Lower Devonian of Loyola and the Tyers River.

Introduction

The writer first became interested in *Cyathophyllum mansfieldense* while preparing a paper on acanthophylloid corals from the Garra Formation of N.S.W. At that time, no specimens could be found, but Mr T. Darragh (National Museum of Victoria) has since made a thorough search of the Sweet Collection, when he found several specimens which he forwarded for examination. A second search by the writer revealed a few more specimens, so that enough were available for a complete revision of Dun's species. One of the specimens proved to be that from which Dun cut his figured sections, and is therefore designated lectotype. Another has thrown considerable light on the wall structure of this particular group of rugose corals. The study has also led to a revision of the subgeneric assignment assumed in Strusz (1966, p. 550).

For discussion of the morphology and taxonomy of the group, the reader is referred to Birenheide (1961).

Specimens in the palaeontological collection of the National Museum of Victoria are indicated by the prefix NMP, those in Sydney University by SUP. Thin section numbers of fossils in the Australian Museum are prefixed by AM. The following abbreviations are used: D_c = corallite diameter, D_t = diameter of tabularium, n = number of septa, n' = number of major septa, L_1 = length of major septa (relative to corallite radius R), L_2 = length of minor septa.

Systematic Description

Genus *Acanthophyllum* Dybowski 1873

Subgenus *Neostriophyllum* Wedekind 1922 *sensu* Birenheide 1961

A. (*Neostriophyllum*) *mansfieldense* (Dun 1898)

Cyathophyllum mansfieldense Dun 1898, p. 87, Pl. 3, fig. 3-4.

Acanthophyllum mansfieldense (Dun); Hill 1939, p. 223, Pl. 15, fig. 1-3.

non *Acanthophyllum* sp. cf. *mansfieldense* (Dun); Hill 1940, p. 152, Pl. 2, fig. 1a, b. This is *Pseudochonophyllum pseudohelikanthoides*—see Strusz 1966, p. 564.

nec *Acanthophyllum?* *mansfieldense* (Dun); Hill 1942a, p. 146, Pl. 2, fig. 1.

nec? *Acanthophyllum* cf. *mansfieldense* (Dun); Hill 1942b, p. 188, Pl. 5, fig. 1. This may be *A. (Neostriophyllum) implicatum*—see Strusz 1966, p. 554.

Acanthophyllum mansfieldense (Dun); Philip 1962, p. 186, Pl. 26, fig. 11-12.
Acanthophyllum mansfieldense (Dun)?; Philip 1962, p. 241, Pl. 26, fig. 9-10.

DIAGNOSIS: Solitary or weakly colonial *Acanthophyllum* with sharp-rimmed inversely conical calice, up to 4 cm diameter; about 56-60 septa strongly dilated wedgewise peripherally, and spindewise in concentric zones, the dilatation often spreading on to dissepimental surfaces making the septa appear as barbed spearheads in transverse section; D_t about 0.3 D_c , tabulae incomplete, tabular floor turned up at dissepimentarium, weakly depressed axially.

TYPE MATERIAL: Dun, when erecting this species, mentioned that it was based on several specimens collected by Sweet from Mansfield, but did not designate a holotype. Hill (1939) based her description on two specimens collected by Ripper, housed in the University of Melbourne. The original material is in the National Museum, as mentioned previously. One of the specimens, already sectioned, bore the old number (probably given by Sweet) LLQ/54. The sections were not in the National Museum, but have since been found in the Australian Museum by Dr A. J. Wright, and bear both the AM numbers, and the number LLQ/54; they are the ones figured by Dun. I here designate as lectotype this specimen NMP 24207, with two sections cut by myself, and the original sections AM 3809, 3810.

The paralectotype specimens in the Sweet Collection are: NMP 24208 (LLQ/7), with one section; NMP 24209 (LLQ/9); NMP 24717, with two sections (and two of *Trapezophyllum elegantulum*); NMP 24718 (LW/44), with two sections (which also contain *Thamnophyllum reclinatum*).

TYPE LOCALITY: Stated by Dun to be limestone outcrops at Mansfield, Victoria; Hill (1939) specified 'Griffith's Quarry, Loyola, near Mansfield', and several of Sweet's specimens are so labelled. See Boueot et al. (1966, p. 367). The limestone, as seen from the matrix of Sweet's specimens, is a medium grey rather stylolitic skeletal calcilutite, containing scattered tentaculitids. The surfaces of the corals show little wear, and are encrusted with equally un-worn auloporids? and calcareous algae. The environment was probably relatively sheltered, and below wave base; the corals seem to be at or near their growth positions.

DESCRIPTION OF LECTOTYPE: The corallites form a small clump, radiating from a point since removed by weathering; this strongly suggests a small colony, but no offsets are visible. The corallites are all slowly expanding adults. Their surfaces appear to be irregularly, but not strongly, wrinkled; septal grooves are lacking. In cross section the corallites tend to be irregularly oval in shape because of mutual interference. The calice seems to be rather deep, with a sharp rim, fairly steep walls showing a gentle sigmoidal curvature, and a narrow concave base having a weak axial depression.

The maximum measured diameter is 29.4 mm; the average of 8 measurements is 22.3 mm. In four transverse sections, the septa number from 54 to 60.

The corallite wall comprises an epitheca about 50 μ thick (appearing as a thin dark film), lining a fibrous stereozone which appears to be in complete structural continuity with the septa. The stereozone is 0.4-1.5 mm wide, averaging about 1 mm. There is no sign of lamellar sclerenchyme.

The septa emerge from the stereozone as wedges up to 2.2 mm long. The dilatation in this peripheral concentric zone is quite variable, but generally strong. There is a fairly regular concentric zone of moderate to strong fusiform dilatation a little outside the tabularium. Adaxially the septa become thin or only slightly dilated; a weak concentric zone of fusiform dilatation may develop just inside the

tabularium. Between these zones the septa remain moderately dilated. In AM 3810, in a sector where the dissepimentarium has extended outward a little, the peripheral zone of dilatation remains concentric, and short segments of only moderately dilated septa separate it (with septa now fusiform) from a narrow peripheral zone of wedge-wise dilatation.

In the zones of dilatation, the tissue spreads over the dissepimental surfaces as fibrous coatings. If these are thin, and particularly if the dissepiments are abaxially geniculate, the effect is to give the septa, in transverse section, the appearance of barbed spearheads pointing to the axis. If they are thick (as in part of AM 3810) a weak inner stereozone may form.

The septa are radial and at most only gently wavy. Their sides are smooth, and develop weak flanges in the tabularium (these are horizontal or inclined upwards at a very low angle); there are neither carinae nor vepreculae (Pedder 1966, p. 181). The peripherally continuous septa may become discontinuous near and in the tabularium. The minor septa are a little unequal, but generally end at the tabularium—i.e. at about $0.7R$ —except in most cases for one pair which may reach $0.8R$. The major septum flanked by this pair is otherwise undistinguished from the others; it may be the cardinal septum, but this cannot be proved. No pattern of septal insertion is otherwise discernible. The major septa, extending unequally towards the axis, may reach it, but generally average about $0.9R$. In one corallite in section NMP 24207a they are uniformly withdrawn to $0.8R$, leaving a circular axial space of 3.7 mm. In another there is double insertion of minor septa, without crowding, in six of the twenty-four major loculi (Fig. 1).

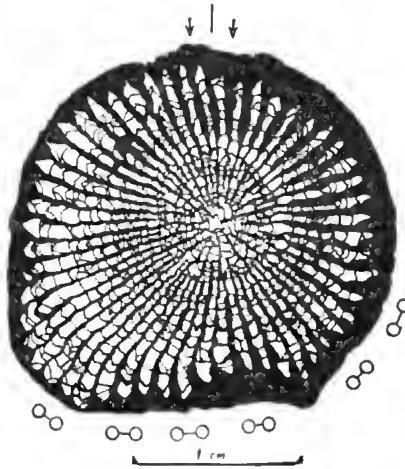


FIG. 1.—Transverse section of one corallite from the lectotype, NMP 24207, approx. $\times 2.0$. Several loculi between major septa are occupied by two minor septa instead of the usual one (indicated by twin circles). Note also the pair of elongate minor septa (arrowed). Drawn from photograph; fibrous dissepimental coatings have been omitted.

The slender trabeculae (generally less than 0.15 mm in longitudinal section) are parallel and densely packed, without intervening lamellar sclerenchyme, and continue into the wall. The microstructure is obscure, but seems to be finely monacanthine. The angle of inclination from the vertical is large, but may differ markedly on opposite sides of a corallite. It is least at about the middle of the

dissepimentarium, increasing moderately abaxially and adaxially. Thus for AM 3809, on one side it is 75° - 60° - 75° , on the other 85° - 70° - 85° .

The dissepiments are rather globose, and variable in size; the number of series varies considerably, depending on the width of the dissepimentarium. As few as 9, as many as 18 have been seen. Peripherally, the dissepiments slope adaxially at about 65° - 70° from the horizontal; in narrow dissepimentaria this inclination gradually increases until the innermost 2-4 series, moderately to strongly elongate, are almost vertical. In wide dissepimentaria there is first a decrease in inclination to as little as 50° , then a gradual increase to about 80° . There is no abrupt change in slope.

$D_t = 0.2 D_e$ to $0.35 D_e$. The tabularium may be a little eccentric. The crowded tabulae are generally incomplete; near the dissepimentarium they are adaxially inclined, arched, and often turned up to meet the dissepiments. At the axis they are flat or gently sagging, with a shallow, weakly to strongly differentiated median depression.

Dimensions of lectotype and paralectotypes

	D_e mm	D_t mm	D_t/D_e	n	n/D_e	L_1	L_2
*AM 3810	c. 22	c. 6	c. 0.27	58	c. 2.64	c. 0.9R	0.65-0.7R
*AM 3809	29.4	5.8	0.20	—	—	—	—
*NMP 24207a	24.0	c. 7.5	c. 0.32	54 ($n'=24$)	2.25	c. 0.9R	c. 0.75R
"	19.8	c. 7.5	c. 0.38	58	2.93	0.81R	0.65-0.7R
"	c. 31	c. 7	c. 0.3	60	c. 2.85	c. 0.9-0.95R	c. 0.65R
*NMP 24207b	19.7	6.6	0.34	—	—	—	—
"	19.4	6.6	0.34	—	—	—	—
"	24.6	7.2	0.29	—	—	—	—
NMP 24208	est. 24	7.0	c. 0.3	—	—	—	—
NMP 24209	c. 19	—	—	—	—	—	c. 0.77R
NMP 24717a	c. 16	c. 5.5	c. 0.34	—	—	—	—
"	c. 26.5	c. 5.5	c. 0.21	50?	c. 1.89	0.9-1.0R	—
NMP 24718	27.3	6.5	0.24	64	2.34	c. 0.9R	c. 0.75R
mean:	22.5	6.6	c. 0.3	57	c. 2.5	c. 0.9R	c. 0.7R

* Lectotype sections; note that for both L_1 and L_2 the average length is generally quoted.

Observations on Paralectotypes

WALL STRUCTURE: Section NMP 24718b clearly reveals the trabecular construction of the wall and septa. The trabecular microstructure is obscure, with some suggestions that it is finely monacanthine. Nevertheless the section is clear enough to show that the septa are essentially unitrabecular (Kato 1963), with the occasional interpolation of narrow trabeculae on one side or the other of the axial plane, and the rare occurrence of a side-by-side pair of trabeculae diverging from that plane. The trabeculae have the shape of laths, tapering inwards as the septal dilatation decreases, and inclined inwards and upwards. These laths are stacked with the wide flat sides together, so that in longitudinal section the minimum width is seen. The wall consists of the outer ends of these laths, lined by a very thin epitheca, whose wrinkles reflect the irregularities of the trabeculae (Pl. 2, fig. 3c). The laths here are about 1 mm wide, 0.15 mm thick. In mid-dissepimentarium the thickness may be as little as 0.10 mm, but is usually about 0.12 mm. The width varies considerably according to the septal dilatation. (Compare Strusz 1966, Fig. 1, and p. 545.)

SEPTAL DILATATION: The zones of dilatation appear to be in the form of successive inverse cones of fibrous tissue, organized into trabeculae within the dilated septa, but spreading as even coatings on to the dissepiments. A transverse section intersecting these cones of dilatation thus gives the impression of concentric zones of fusiform dilatation.

$D_t : D_c$: The data are insufficient for rigorous statistical treatment, particularly as there are no juvenile corallites. For the known size range ($D_c > 16$ mm), a plot of D_t/D_c against D_c on logarithmic coordinates strongly suggests an allometric relationship between the two variables. The corallites figured by Philip (1962, Pl. 26, fig. 9, 11-12) from the Tyers area agree well with this pattern (Fig. 2).

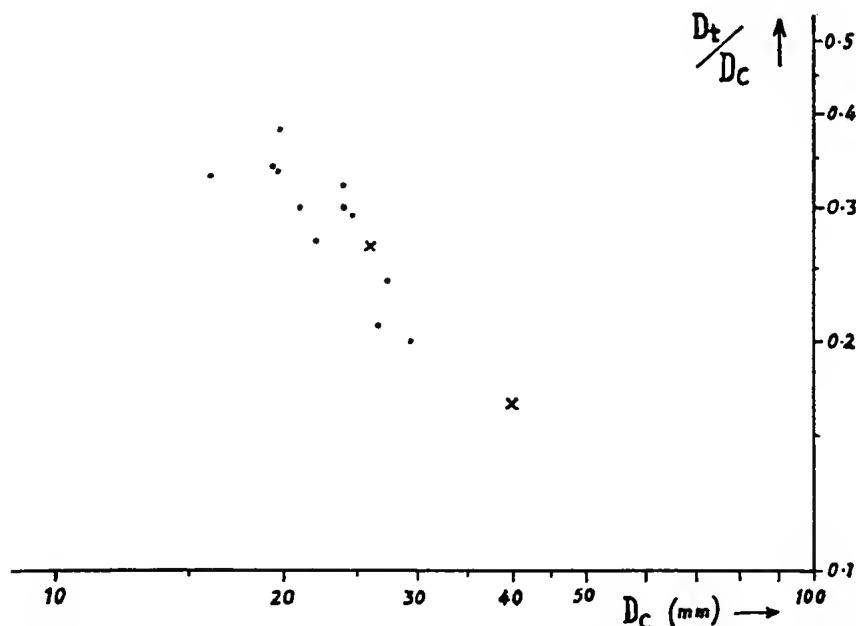


FIG. 2—Plot of D_t/D_c against D_c for *A. (N.) mansfieldense* on logarithmic coordinates. Philip's figured corallites are shown by crosses.

COMPARISON: Both Hill (1939) and Philip (1962) have remarked on the similar strong peripheral septal dilatation in this species and *Cyathophyllum baculoides* Počta in Barrande 1902 (from Koněprusy and also from the Chalonnes limestone; see Le Maître 1934). Unfortunately neither Počta nor Le Maître figured longitudinal sections, and their descriptions of the horizontal tissue are brief. In transverse section, marked difference from *A. (N.) mansfieldense* lies in strong vortical rotation of the axially dilated septa, and in the presence peripherally of numerous naotic plates. Počta also reports a higher septal number. *C. baculoides* is strongly reminiscent of *Dohmophyllum* as described by Birenheide (1963), or possibly *Pseudochonophyllum* Soshkina *sensu* Strusz 1966. Longitudinal sections are required before the precise affinities of Počta's species can be ascertained.

Hill's (1942a, p. 146) doubtful example from the Nemingha Limestone of Attunga, N.S.W. consists of a transverse section of two acanthophylloid corals with extremely dilated septa (Pl. 2, fig. 4). The one complete corallite has $D_c = 21.4$

mm, $D_t = c. 6.5$ mm, and $n = 42$. This septal number is significantly lower than that of corallites of the same diameter from Loyola. Septal dilatation alone is unreliable, but taken with this difference in n/D_c there is little doubt that the Nemingha coral is distinct from *A. (N.) mansfieldense*. More material is needed before its affinities can be determined.

REMARKS: The first problem met with in analyzing the relationships of this species is the form of the corallum. Of the acanthophylloid species, solitary corals have been placed in *Acanthophyllum* (see Birenheide 1961), fasciculate corals in *Lyriellasma* (see Strusz 1966). It seems likely that *A. mansfieldense* may be at one time solitary, at another weakly fasciculate, forming small clumps of a few corallites. Probably, in the second case, the original corallite has the capacity to form a few buds, which reach full size but do not themselves bud. I have conclusively observed the same phenomenon in some corals from the Garra Formation comparable with *A. (A.) clermontense* (see Strusz 1966, p. 552). Should these species be considered as essentially colonial, or essentially solitary? Birenheide (1964) has already decided that colony-form is at best a specific character among the solitary and fasciculate Devonian 'eystimorphs'. Among solitary and fasciculate acanthophylloid corals, I consider it is possible to discern two groups. One consists of those species which are exclusively fasciculate, forming colonies by repeated budding—these I would place in *Lyriellasma*. The other consists of species which either never bud, or do so only occasionally, to form small 'clumps' of a few radiating corallites; these are *Acanthophyllum*.

The other problem is that arising from Wedekind's multiplicity of genera, and Birenheide's (1961) revision of these. *A. mansfieldense* does not have the bell-shaped calice such as Birenheide considers typical of the German *A. (Acanthophyllum)*, yet its calical sides are often sigmoidally curved to a certain extent. On the basis that there is no abrupt strong change in inclination of dissepiments and trabeculae a little abaxially from the tabularium, I am inclined to broaden slightly the scope of the 'inversely conical calice' (*Trichterkelch*) characteristic of the subgenera *Grypophyllum* and *Neostingophyllum*, to include calices such as that of *A. mansfieldense*. The essential features of such a calice are sharp rim, steeply sloping straight or sinuous sides, and concave floor.

The nature and strength of the septal dilatation, and the thick dentate wall, agree most closely with Birenheide's conception of *A. (Neostingophyllum)*, but it should be kept in mind that the separation of this subgenus from *A. (Grypophyllum)* may yet prove invalid. The type of *A. (Neostingophyllum)* needs further investigation.

In Strusz (1966, p. 550) the species was grouped with *A. clermontense* as a large-diameter species of *A. (Acanthophyllum)*, distinguished by its distinctive septal dilatation and smaller number of septa. This is now seen to be incorrect.

OCCURRENCE: As now understood, the species is known with certainty from Loyola and the Tyers R. Boucot et al. (1966) note that the coralline and brachiopod faunas of the two are very close, and indicate a 'probably Upper Siegenian' age.

Acknowledgements

Most of the work for this paper, including a visit to Melbourne which provided the opportunity for a search through the Sweet Collection, was financed by the University of Queensland while I was on the staff of the University College of Townsville. I should like to express my thanks to Mr T. Darragh of the National

Museum for kindly lending me the original specimens, and for permitting new sections to be prepared from the lectotype. Sincere thanks are also due to Dr A. J. Wright for information on the whereabouts of Dun's sections, and to Mr H. O. Fletcher for sending me photographs of them. Prof. D. Hill assisted greatly by her useful criticism of the manuscript. The paper is published by permission of the Director, Bureau of Mineral Resources, Geology and Geophysics.

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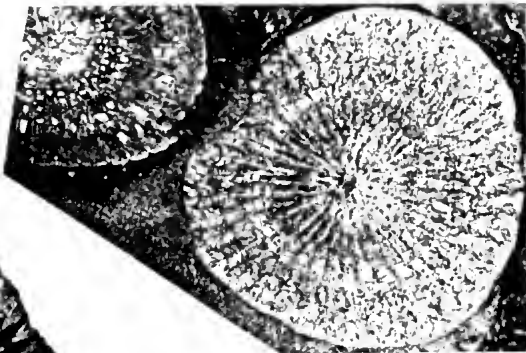
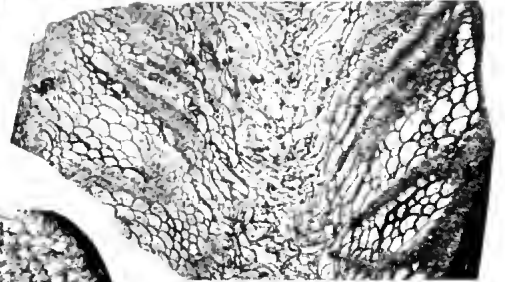
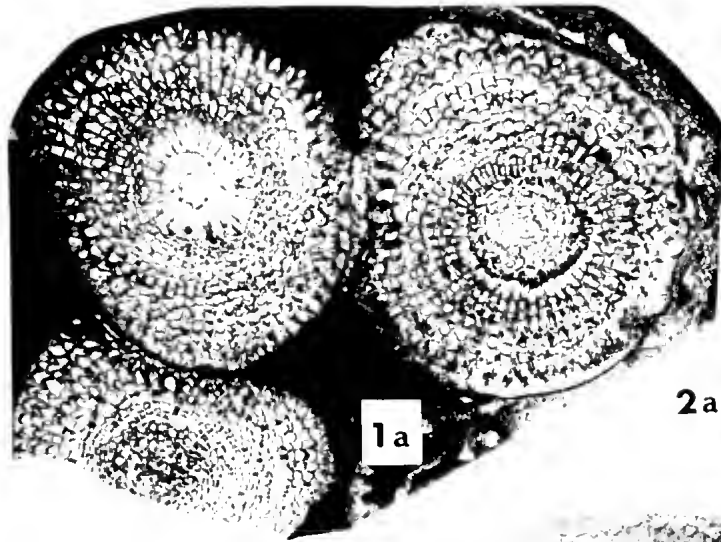
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Explanation of Plate

PLATE 2

- The photography for fig. 1 and 3 was done by Mr. C. Zawarko of the Bureau of Mineral Resources; fig. 2 is by courtesy of the Australian Museum; fig. 4 was taken by the writer. All are $\times 2.0$ except fig. 3c, d, which are $\times 5.0$.
 Fig. 1—*Acanthophyllum* (*Neostrophophyllum*) *mansfieldense*. Lectotype, NMP 24207; the longitudinal section (b) is of the top right corallite in (a).
 Fig. 2—*A. (N.) mansfieldense*. Lectotype, AM 3809 (longitudinal section b) and AM 3810 (transverse section a); original sections, figured Dun 1898, Pl. 3, fig. 3-4.
 Fig. 3—*A. (N.) mansfieldense*. Paralectotype, NMP 24718. Enlargements (c, d) show details of the trabecular construction of wall and septa. The small corallite in 3b is *Thamnophyllum reclinatum*.
 Fig. 4—'*Acanthophyllum* ?*mansfieldense*' of Hill 1942a, Pl. 2, fig. 1. SUP 7254, Nemingha Limestone, Attunga, N.S.W. Note the difference in mode of septal dilatation from *A. (N.) mansfieldense*.





ON THE OCCURRENCE OF THE TRILOBITE GENERA *ACASTE* AND *ACASTELLA* IN VICTORIA

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Abstract

Acaste longisulcata sp. nov. and *Acastella frontosa* sp. nov. are described from the Ruddock Siltstone of the Lilydale district of Victoria. These species are the first undoubted representatives of their genera to be recorded from the southern hemisphere. The species of *Acaste* becomes the youngest (in the stratigraphical sense) yet reported. It is compared in general terms to *Acaste dayiana* Richter & Richler 1954 while *Acastella frontosa* is compared in similar terms to *A. patula* Hollard 1963 and *A. rouaulti* (de Tromelin & Lebesconte 1875). The age of the Victorian species is Lower Devonian. In terms of north-west European stratigraphy they occur within the time span, high Lower Gedinian to Siegenian.

Introduction

Apart from the reference by Gill (1940, p. 241, 253) to *Phacops* (*Acastina*) the genera *Acaste* and *Acastella* have not previously been reported from Australia, though the species described below were actually noted and figured by Chapman (1915, p. 168-9, Pl. XV, fig. 14, 15) under the nomen *Phacops crossleii* Etheridge fil. and Mitchell. The genera exist contemporaneously in beds of Lower Devonian age in the Lilydale district of Victoria.

The occurrence of *Acaste longisulcata* sp. nov. in beds of this age is of interest from the point of view of both spatial and temporal distribution, for the species becomes the stratigraphically youngest attributed to the genus and is the first true *Acaste* to be recorded from the southern hemisphere. Though species of the genus have been reported from South America, the actual occurrence may be doubted. Of the species in question *Acaste lombardi* Kozłowski 1913 (Ponta Grossa Shales, Paraná, Brazil), *A. verneuili* (d'Orbigny 1842) (Isla Formation, Sicacica Formation, Bolivia), *A. perplana* Knod 1908 (*Connularia* and *Lingula* Sandstones, Jachal, Argentina), and *A. cordobesa* Méndez-Alzola 1938 (lateral equivalents of the Ponta Grossa Shales, Rincón de Alonso, Arroyo del Cordobés, Uruguay) are most certainly better referred to the genus *Acastoides* Delo 1935, while *Acaste convexa* (Ulrich 1892) has many features comparable to *Calmonia subseciva* Clarke 1913.

Acastella frontosa sp. nov. also represents the first undoubted record of the genus from the southern hemisphere. Reed (1925) described the species *Dalmanites* (*Acastella*) *pseudoconvexus* from the Bokkeveld Beds of South Africa but his illustration of the cephalon (Pl. 9, fig. 8) is too poor to permit critical interpretation in the light of recent work in Europe (Richter & Richter 1954, Pillet 1959, 1961, Tomezykova 1962, Hollard 1963, Shergold 1967).

In the following text, specimens from the National Museum of Victoria are labelled VNM, those from the Geological Survey of Victoria, GSV, and those from the Geological Survey Museum, London, GSM.

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Symbols utilized for parameters, and proportions quoted in the descriptions are basically those of Struve (1958, p. 167). They are defined as follows: A, exsagittal length of eye; H, distance between the back of the eye and the posterior border furrow; G, sagittal glabellar length; Gn, sagittal glabellar length plus the sagittal dimension of the occipital ring H:A; A:G (large eye index); A:Gn (small eye index).

Systematic Descriptions

Family DALMANITIDAE Vogdes 1890

Subfamily ACASTINAE DcIo 1935

Genus *Acaste* Goldfuss 1843

Acaste longisulcata sp. nov.

(Pl. 4, fig. 7-8; Pl. 5, fig. 1-12)

1915 *Phacops crossleii*, Etheridge fil & Mitchell (pars.); Chapman 1915, p. 168-9, Pl. XV, fig. 15 (VNM P12680, pygidium).

1940 *Phacops (Acastina)*, sp. nov. (?); Gill 1940, p. 251, 253.

DERIVATION OF NAME: A species of *Acaste* with all three pairs of lateral glabellar side furrows reaching further towards the sagittal line than in any other known species; hence long furrows latinized—*longisulcata*.

TYPE: Holotype (here designated); the complete pygidial internal mould, VNM P12680, figured by Chapman (1915, Pl. XV, fig. 15), refigured here Pl. 4, fig. 7-8.

LOCALITY AND HORIZON OF TYPE: Ruddock's Quarry, approximately 1½ miles NW. of Lilydale railway station, Lilydale, Victoria; Gill locality 20 (Gill 1940, p. 252, Fig. 1).

Ruddock Siltstone, Yering Group (sens Gill 1965, p. 119), Lower Devonian (possibly Siegenian, see below).

MATERIAL AND OCCURRENCE: *Acaste longisulcata* sp. nov. occurs in the Ruddock Siltstone of the Lilydale area, Victoria. In these beds the type specimen, which Chapman (1915, Pl. XV, fig. 15) considered to represent the pygidium of *Phacops crossleii* Etheridge & Mitchell, was obtained from Ruddock's Quarry (Gill 1940, Fig. 1, locality 20). It is a large but complete internal mould which has suffered slight lateral distortion, and is undoubtedly a late holaspide individual. Its length (sag.), from the transverse furrow, separating the articulating half ring from the first axial ring, to the posterior margin, measures 8.80 mm. The axial length (sag.) is 7.60 mm, the axis thus occupying 86% of the total length. The maximum width (tr.) of the pygidium amounts to 15.65 mm, while that of the axis at the first ring measures 4.85 mm. Anteriorly the axis thus occupies 31% of the total pygidial width.

A considerable amount of supplementary material has been collected recently by Mr E. D. Gill, consisting of numerous disarticulated cephalons and pygidia. While the general condition of preservation is good, all the specimens available are to some degree distorted by lateral or oblique compression. These specimens are all considerably smaller than the type and represent in the main early holaspide morphogenetic stages. The additional material was collected from a quarry on the north side of the Maroondah Highway, W. of Black Springs, Lilydale (this being Gill's locality 50, unpublished). Gill (1940, p. 251) also referred to *Phacops*

(*Acastina*) from a cutting on the main Melbourne-Lilydale road between North Croydon and Black Springs (Gill 1940, locality 18). Reference to Gill's Fig. (op. cit.) shows that all the localities mentioned above lie within the same general area and indeed are within $\frac{1}{2}$ mile of each other.

To the species *Phacops crossleii* Eth. & Mitch. sens Chapman (1915, p. 168-9) (= *Acaste longisulcata* sp. nov.) Chapman also referred specimens from Kinglake West and from a branch of the Saltwater River, one mile W. of Gisborne. These specimens, respectively VNM P12682 and P1218, have been re-examined and are considered not referable to *Acaste*.

The cranidium figured by Talent (1964, p. 57, Pl. 27, fig. 7) as 'Dalmanitidae gen. indet. C' from the Mt Ida Formation of the Heathcote district of Victoria does, however, represent a species of *Acaste*. Further cranidia were collected on the 1967 ANZAAS excursion to this area by Dr J. A. Talent. As yet the author has examined only a limited number of specimens, rather indifferently preserved, and hesitates to compare too closely this material with the species under consideration.

DIAGNOSIS: A species of *Acaste* Goldfuss 1843 having, in the undistorted condition, a markedly triangular cephalic outline as in *Acaste dayiana* Richter & Richter 1954; proportionately narrow (tr.) glabella; long glabellar furrows extending inwards to within a very short distance of the sagittal line; pygidium with strong convexity (tr.), 8 axial rings, 5-6 pleural segments; lacking a marked marginal furrow on both shell and internal mould.

DESCRIPTION: Cephalic outline triangular to subtriangular; cephalic surface very finely granulose.

Glabella proportionately long (sag.) and narrow (tr.), with greatest width (tr.) across the frontal lobe; tapering evenly to the posterior, the confining axial furrows diverging forwards at approximately 16 degrees; anteriorly and antero-laterally broadly rounded; in lateral profile with low to moderate convexity (sag.) across the frontal lobe, flat across the side lobes. Anterior lateral glabellar lobes distinctly subtriangular in small specimens, more nearly subrectangular in larger ones; median lateral glabellar lobes subrectangular, posteriorly curved; preoccipital lobes narrow (exsag.), about $\frac{2}{3}$ as wide (exsag.) as the preceding lobes, with slightly greater convexity (tr.).

Anterior lateral glabellar furrows strongly incised as in most other species of *Acaste*, sigmoidal, with distinct posterior median deflection; a gap is left a little less than one-fifth the width of the glabella between the adaxial ends of these furrows, which is smaller than in many other species of the genus; median lateral furrows a little more deeply incised, shorter, linear, transverse, not reaching the axial furrows laterally, adaxially slightly more distant from the sagittal line than the ends of the anterior pair of furrows; preoccipital furrows much deeper and wider (exsag.), strongly curved, with both adaxial and abaxial curvature to the anterior and a tendency for the former to converge towards the ends of the anterior lateral furrows. A short sagittal furrow runs longitudinally across the basal $\frac{1}{4}$ of the frontal lobe, commencing between the adaxial ends of the anterior pair of furrows.

Occipital furrow as deep abaxially as the preoccipital furrows, shallow mesially, widening sagittally. Occipital ring slightly wider (tr.) than the preoccipital lobes but with similar convexity (tr.); rising in lateral profile well above the level of the glabellar side lobes.

Genae evenly convex, without appreciable marginal furrow; postero-laterally acutely angled in late holaspides (Pl. 5, fig. 1-2) and minutely spined in early

holaspides (Pl. 5, fig. 3, left gena), comparing closely in this respect with the development of the genal angle in *Acaste downingiae* (Murchison) (Shergold 1966, p. 189-190). Preocular section of the facial suture marginal or just dorsal intra-marginal, running concentric to the contour of the frontal glabellar lobe; postocular section cutting the lateral cephalic margins approximately opposite the middle of the preoccipital lobes.

Eyes of normal size, situated on low ocular platform, close to glabella; extending from the level of the middle of the preoccipital lobes to the confluence of the anterior lateral glabellar furrows and the axial furrows; A:Gn 39-42%; A:G 45-50%; H:A 16-25%. Palpebral lobes prominent, palpebral areas narrow (tr.). Visual surface known from a single immature specimen showing 6 lenses alternating with 7 at the maximum height of the surface.

Nature of hypostome and thorax unknown.

Pygidium with semicircular outline in all specimens, subtriangular in large specimens; with entire margin, posteriorly rounded. Axis with moderate convexity (tr.), occupying about 85-90% of the total pygidial length, terminating abruptly; composed of 7 rings in small and 8 in large specimens. Pleurae strongly convex (tr.), with 5 segments in early holaspides, 6 in late holaspides; pleural furrows rather narrow (exsag.); interpleural furrows relatively well-defined separating all segments. Border wide and without marginal flattening in small specimens, narrower with a poorly-defined furrow in large individuals.

RELATIONSHIPS: *Acaste* is an homogenous genus, species being differentiated on the basis of character complexes rather than single characteristics. Features important in distinguishing species within the genus are: the overall geometry of outline of cephalon and pygidium; relative proportions and shape of glabella; the convexities and proportions of its lobes and the relative lengths and courses of its furrows; the angle of divergence forwards of the axial furrows; the relationship between frontal lobe, preglabellar area and anterior cephalic margin; size and position of the eyes and contents of the visual surface; segmentation of the axis of the pygidium, its relative length, width and convexity; the presence or absence of a marginal furrow or flattening in the pygidium and the width of the border.

In its geometry of cephalic outline *Acaste longisulcata* sp. nov. approaches that of *A. dayiana* Richter & Richter 1954 and the *Acaste* sp. from South Wales figured by the Richters (1954, Pl. 3, fig. 44) and refigured here (Pl. 5, fig. 13-14) for comparison. The outline is decidedly triangular and is thus differentiated from species with more subpentangular outlines, such as *A. downingiae* (Murchison 1839) and *A. inflata* (Salter 1864). The pygidium is wider (tr.) than in most other *Acaste* species but this observation may be influenced by preservation.

In its glabellar shape and convexities the Australian species again approaches *A. dayiana*, *A. downingiae*, *A. inflata* and *A. subcaudata* (Murchison 1839). All have a wider (tr.) glabella with axial furrows diverging anteriorly at lesser angles, i.e. they are more nearly parallel-sided. *A. longisulcata* is unique in the length of its furrows. The convexity of the frontal lobe (sag.), however, recalls both *A. dayiana* and *A. inflata*, but the convexities of the lateral lobes are considerably less than in the latter species.

The narrow, triangular area of librigena which lies between the frontal lobe and the slightly angled anterior preocular section of the facial suture in *A. downingiae*, *A. inflata*, *A. subcaudata* and *A. dayiana* is much reduced in *A. longisulcata*.

The proportions establishing the size of the eyes in species of *Acaste* with respect to the glabellar lengths and distance from the posterior border furrow are listed below:

	A : G	A : Gn	H : A	Lenses at max. of vis. surf.
<i>A. downingiae</i>	46-67	37-54	12-30	7(8)/8(9)
<i>A. inflata</i>	47-56	40-48	5-18	6/7
<i>A. subcaudata</i>	45-63	37-46	12-27	5/6
<i>A. longisulcata</i>	45-50	39-42	16-25	6/7
<i>A. dayiana</i>		Not obtained		5/6

The eyes of *A. longisulcata* are perhaps closer to the glabella than in many species of the genus but appear to be situated with reference to the posterior border furrow in a comparable position. In the content of the visual surface *A. longisulcata* is comparable to *A. inflata*. There are fewer lenses than in *A. downingiae* but more than in *A. dayiana* and *A. subcaudata*.

As in *A. downingiae* the early holaspis pygidial borders are non-furrowed. In *A. subcaudata* moulds of comparable size show a marginal furrow. In *A. dayiana* a furrow is developed on the mould but the shell is non-furrowed. The overall pygidial segmentation, with 5-6 pleural segments and 7-8 axial rings, is comparable to that of *A. inflata* and *A. subcaudata*. *A. downingiae*, *A. dayiana* and *A. talebensis* Hollard 1963 have extra rings in the axis, 7-9, 7-10 and 8 respectively and there may also be an additional pleural segment.

Several of the observed differences between *A. longisulcata* and other species may be influenced by the fact that a full range of specimens covering the total size span of the species is not available. Further, some species are known largely from moulds, others largely from specimens preserved with the shell. Detailed morphogenetic changes within the species cannot therefore be elucidated at the time of writing. Nevertheless *A. longisulcata* does, during morphogenesis, show similar trends to the changes occurring in the type species, *A. downingiae*, the only species known in considerable detail (Shergold 1966). In common with that species, with *A. subcaudata* and possibly also other species of the genus, *A. longisulcata* possesses mucronate genae in the earliest holaspis morphogenetic stages. The genae of late holaspides are likewise acutely angled or rounded off. Similarly there is a general increase during the holaspis morphogenesis in the degree of segmentation of the pygidium.

Genus *Acastella* Rced 1925

Acastella frontosa sp. nov.

(Pl. 3, fig. 1-4; Pl. 4, fig. 1-6)

1915 *Phacops crossleii*, Etheridge fil & Mitchell (pars.); Chapman 1915, p. 168-9, Pl. XV, fig. 14 (VNM P12679, nearly complete individual).

DERIVATION OF NAME: L. *Frontosa*, describing the anterior cranial process which lies between the frontal glabellar lobe and the preocular section of the facial suture.

TYPE: Holotype (here designated); the nearly complete internal mould of a large individual figured by Chapman (1915, Pl. XV, fig. 14), refigured here Pl. 3, fig. 1-3, VNM P12679.

LOCALITY AND HORIZON OF TYPE: Ruddock's Quarry, approximately 1½ miles NW. of Lilydale railway station, Lilydale, Victoria.

Ruddock Siltstone, Yering Group, Lower Devonian (possibly Siegenian).

MATERIAL AND OCCURRENCE: The holotype is very nearly complete but somewhat distorted; the left gena has exaggerated convexity and has lost the palpebral lobes and the visual surface; the caudal mucronation of the pygidium is not preserved and the axial region has been lost; genal mucronations have also been eroded away.

Several other examples of this species have been located. A second nearly complete individual from the National Museum of Victoria, VNM P26076, lacks only the posterior part of the pygidium. Of the three specimens from the collections of the Geological Survey of Victoria figured here (Pl. 3, fig. 4; Pl. 4, fig. 1-6), the cranidium, GSV 61859, and the cephalon, GSV 61860, show to advantage the genal spines and glabellar convexities but the pygidium, GSV 61861, again lacks the caudal mucronation.

Early holaspid morphology remains unknown at the time of writing, the available material representing late holaspid morphogenetic stages.

The holotype possesses the following dimensions and proportions: Length of cephalon (estimated), 14.15 mm; Length of glabella plus occipital ring, Gn, 13.75 mm; Length of glabella, G, 11.90 mm; Length of eye, A, 5.05 mm; Distance of eye from posterior border furrow, H, 1.30 mm; Width of frontal lobe, 10.05 mm; Width of preoccipital lobes (estimated), 6.00 mm; Length of thorax (estimated), 20.55 mm; Length of pygidium (estimated to spine base), 10.45 mm; Width of pygidium (estimated), 15.75 mm; the eye occupies 42.5% of the glabellar length (A : G) and 37% of the length of the glabella plus occipital ring (A : Gn); the distance between the back of the eye and the posterior border furrow (H) amounts to 25.75% of the eye length (A) (ratio H : A).

Acastella frontosa sp. nov. occurs together with *Acaste longisulcata* sp. nov. in the Ruddock Siltstone of Ruddock's Quarry, Lilydale (Gill 1940, Fig. 1, locality 20), an horizon lying some 1000-1500 ft above the base of the formation. Further specimens are figured here from 'red shales outcropping by a road cutting 14 chains from the Melbourne-Lilydale highway, $\frac{1}{2}$ mile west of Lilydale', this locality being known as 'Hull Road, Lilydale' (Gill 1940, p. 257, Fig. 1, locality 1). This horizon lies considerably above that of Ruddock's Quarry. There is another specimen in the collections of the National Museum of Victoria from the locality known as 'Wilson's' on 'the old Melbourne road, near the top of the hill, about $\frac{1}{2}$ mile above Lilydale' (Gill, op. cit., p. 257, locality 2). The horizon of this outcrop lies at a comparable stratigraphical level to that of 'Hull Road, Lilydale'.

DIAGNOSIS: A species of *Acastella* Reed 1925 with a very prominent, triangular, forward extension of the anterior cranidial margin lying immediately in front of the glabella, defined by the preocular section of the facial suture produced into angles between 40-45 degrees, imparting to the cephalic outline a markedly ogival aspect; axial furrows curving outwards at the level of the median lateral glabellar lobes furrows, drawn in at the level of the preoccipital and anterior furrows; preoccipital furrows with distinct angle in their middle courses causing a constriction and distal expansion of the preoccipital lobes; pygidium with wide (exsag.), channel-like pleural furrows of dalmanitoid appearance.

DESCRIPTION: Cephalic outline ogival to subpentangular, anteriorly distinctly angled; cephalic surface finely granulose.

Glabella anteriorly gently angled, antero-laterally sharply angled or rounded depending on preservation; widest (tr.) across the frontal lobe, decreasing irregularly in width (tr.) to the posterior. Axial furrows defining the glabellar outline

drawn in slightly at the anterior lateral and preoccipital furrows, expanding outwards at the median lateral furrows.

Frontal lobe long (sag.), with low to moderate convexity (sag.) in lateral profile; bearing on the internal mould 4 or 5 rows of tubercles, radiating across the convexity of the lobe from a point between the adaxial extremities of the anterior lateral furrows; on the cast from the external mould a short longitudinal furrow lies sagittally in this position. Anterior lateral lobes nearly as wide (tr.) as the frontal lobe, triangular, fused abaxially with the median lateral lobes; the latter are narrower (tr.) than the anterior lobes and are subrectangular, with strong posterior curvature; preoccipital lobes narrow (exsag.), $\frac{2}{3}$ as wide (exsag.) as the median lateral lobes, with slightly greater convexity (tr.), a slight constriction in the middle section of these lobes contrasts to a distal expansion.

Anterior lateral furrows shallow, wide, opening slightly abaxially, sigmoidal in smaller specimens with marked posterior median deflection, straighter, more nearly oblique in larger specimens; median lateral furrows shorter, linear, transverse, a little shallower than the anterior furrows, without median deflection to the posterior, failing laterally to reach the axial furrows; preoccipital furrows deep and wide, strongly curved both adaxially and abaxially to the anterior, there being a marked 'elbow' at the meeting of these curvatures in the centre of the furrow. There is only a faint tendency for the adaxial convergence of the preoccipital and anterior lateral furrows.

Occipital furrow relatively wide (sag. and exsag.), slightly constricted sagittally, deep abaxially. Occipital ring slightly less wide (tr.) than the preoccipital lobes but with somewhat greater convexity (tr.); wide (sag.); in lateral profile barely rising above the level of the glabellar side lobes.

Genae subtriangular, moderately convex, without appreciable marginal furrow or flattening; posterior margin of cephalon sinuous, with stout postero-lateral spines apparently developed as a backwards extension of the lateral cephalic margins. Postocular sections of facial suture cutting lateral cephalic margins nearly opposite the level of the occipital furrow; preocular section following the lateral and antero-lateral margins of the frontal lobe but deviating from this course anteriorly, forming sagittally a markedly acute angle of 40° - 45° ; between the margin of the frontal lobe and the preocular facial suture a narrow band, representing the cranial border, is retained antero-laterally, becoming anteriorly produced into a very distinct and characteristic conical projection, inclined very slightly upwards (Pl. 4, fig. 4).

Eyes subrescent in plan view, posteriorly close to the glabella and to the posterior border furrow; extending from the level of the posterior edge of the preoccipital lobes to the confluence of the anterior lateral furrows and the axial furrows or from the preoccipital furrows to a position slightly in front of that confluence; in anterior profile rising to the level of the top of the glabella surface. Visual surface with 7 or 8 lenses at its maximum vertical height. Palpebral lobes prominent, somewhat wider posteriorly; palpebral furrows well-defined, tightly curved; palpebral areas posteriorly narrow. Proportions indicating the size and position of the eyes cannot be given accurately from the small number of specimens known but the following variation is suggested from those measured: A:G, 35-49%; A:Gn, 43-58%; H:A, 15-26%.

Nature of hypostome unknown.

The thorax is known only from the internal mould of the holotype. Nevertheless as the thorax is imperfectly known in species of *Acastella* this single specimen warrants considerable attention. It is composed of 10 segments and in its general

appearance is strongly reminiscent of the thorax of *Acaste* species. The axis, occupying a little greater than one-third the total width (tr.), is widest (tr.) at the 4th and 5th rings. Transverse furrows are wide and shallow, defined on either side of the sagittal line by deep, ovoid, apodemal pits. The rings themselves are distally expanded (Pl. 3, fig. 1, 2), similar to the preoccipital glabellar lobes. Pleural segments are divided by deep pleural furrows, commencing near the apodemal pits and cutting obliquely at first, thence flattening out to follow the anterior margin of each pleuron; distally somewhat curved and reaching nearly to the distal margin. Propleuron relatively narrow proximal to the axial furrows, wider distally with smooth antero-lateral articulating facet. Opisthopleuron approximately blade-shaped, its posterior margin curving distally backwards, then forwards culminating in a short point, much the same as the outline of the posterior cephalic border. The pleural furrows extend distally to the bases of the pleural points.

Pygidium broadly subtriangular in outline, rather strongly vaulted (tr.). Axis strongly convex (tr.), evenly tapering to the posterior, extending nearly to the posterior margin; possibly 8 rings plus a terminal piece. There are 6 pleural segments, divided by wide (exsag.), channel-like pleural furrows which extend nearly to the margins. Interpleural furrows considerably weaker but remaining well-defined, especially adjacent to the axial furrows. Border very narrow with irregular swellings, discernible in certain conditions of lighting. Margin entire; caudal mucronation not preserved on the available material.

VARIATION: The available specimens, while being compatible in the majority of characteristics, do show some variation in the size of the eye. The single specimen from the horizon of Ruddock's Quarry has distinctly smaller eyes than the specimens from Hull Road, Lilydale. With the small number of specimens presently available it is not possible to say that this variation lies outside that which can be normally expected in an acastinid species. In some acastomorph genera, e.g. *Acastocephala*, there is a measurable increase in the size of the eyes during holaspis morphogenesis (Shergold 1966).

RELATIONSHIPS: Species of *Acastella* may be divided on pygidial characteristics into two distinct groupings, these being based on the presence or absence of marginal denticles on the late holaspis internal moulds. It is only the late holaspides which can be differentiated in this manner, however, as it is suspected that a denticulate condition is exhibited in the early holaspis morphogenetic stages of most species of the genus. Three species have denticulate late holaspis moulds: *A. tiro* (Richter & Richter 1954), *A. elsana* (Richter & Richter 1954) and *A. rouaulti* (de Tromelin & Lebesconte 1875) and these are accordingly readily differentiated from *A. frontosa* sp. nov. Species with non-denticulate pygidial margins are more numerous and it is with these that the Australian species is allied. They include the type species *A. spinosa* (Salter 1864), *A. prima* Tomczykowa 1962, *A. heberti* (Gossellet 1888), *A. patula* Hollard 1963, *A. granulosa* Hollard 1963 and *A. jacquemonti* Hollard 1963.

A. frontosa is distinguished from most of these species in its glabellar outline, expanding outwards instead of drawn in at the median lateral glabellar furrows, and in its possession of a prominent frontal process. This latter peculiarity is perhaps the most interesting feature of *A. frontosa*. No other species of *Acastella* exhibits the characteristic exaggerated to the same degree, although both *A. rouaulti* and *A. patula* have a distinct angulation of the preocular facial suture anterior to the glabella (Pillet 1959, p. 940, Fig. 1; Hollard 1963, Pl. 2, fig. 1, Pl. 3, fig. 17). In both species a narrow cranial border is formed antero-laterally to the frontal

lobe, as in our species. It is in other related genera, however, that the peculiar diagnostic feature of *A. frontosa* is developed to a comparable extent. Compatible structures are present in the specimen figured by Hollard (1963, Fig. 9) as ? '*Asteropyge*' sp. *M* Richter & Richter 1954. They are also present in *Cryphaeoides rostratus* (Kozłowski 1923), *Schizostylus brevicaudatus* (Kozłowski 1923) and *Dalmanitulus weberi* Chernysheva 1937 (p. 14, Fig. 3). In *Calmonia signifer* Clarke (1913, Pl. 6, fig. 1, 3, 4) an apparently similar structure is developed from the librigena anterior to the preocular facial suture and in the genus *Paracalmonia* a true spine is present in this position (Clarke 1913, Pl. 7, fig. 11-13, 16, 19). The anterior cranidial process obviously develops initially from the condition shown by *Acastella tiro* (Richter & Richter 1954, Pl. 5, fig. 73d) in which a small deltoid area, encompassed within a distinctly angled facial suture, lies within the normal cephalic margins.

The deep and wide pleural furrows of *A. frontosa* are dalmanitoid in appearance. Among species of *Acastella* only *A. patula* (Hollard (1963, Pl. 2, fig. 2, 3 and Fig. 2c) has similar furrows but they may also be compared with those of *Treveropyge ebbae* (Richter & Richter 1954, Pl. 6, fig. 91). Though a caudal spine is preserved in none of the available specimens the general shape of the postero-lateral pygidial margins suggests that this would not have been large, probably of comparable size to that of *A. patula* Hollard (1963, Fig. 2c), *A. jacquemonti jacquemonti* Hollard (op. cit., Fig. 4b) or *A. j. levis* Hollard (op. cit., Fig. 6a).

A Comment on the Age of *Acaste longisulcata* and *Acastella frontosa*

Species of *Acaste* and *Acastella* occur most frequently in NW. Europe and N. Africa. In these areas the range of *Acaste* extends from the Middle Silurian, Upper Wenlockian (Wenlock Limestone) of the British Isles—*A. downingiae* and *A. inflata* (Shergold 1966)—to the Lower Devonian, mid-Lower Gedinian (Upper Oudai Hara Formation) of SW. Morocco—*A. talebensis* (Hollard 1963). The genus *Acastella* ranges from the Upper Silurian, Ludlovian (Upper Leintwardine Beds of Holland, Lawson & Walmsley 1963) of the British Isles—*A. spinosa* (Shergold 1967)—and Siedlce Beds of northern Poland—*A. prima* (Tomczykowa 1962)—into the Lower Devonian, Siegenian (Grès à *Dalmanella monnieri*), Massif armoricain, Central France (Pillet 1959)—*A. rouaulti*—and beds of comparable age, Talmadert Formation, in south-west Morocco (Hollard 1963). In the Rzepin Beds (Podlasiian) of southern Poland and in the Upper Oudai Hara Formation (Lower Gedinian) of south-west Morocco species of *Acaste* and *Acastella* co-exist. A similar situation is observed in the Ruddock Siltstone of Victoria.

The Ruddock Siltstone Formation of the Lilydale area, 8000 ft thick (Gill 1965, p. 119), is succeeded by the Lilydale Limestone and Cave Hill Conglomerate Formations. The three formations together constitute the Yering Group as defined by Gill (1965). The Lilydale Limestone has become generally regarded as of late Lower Devonian age on the basis of its coral and stromatoporoid faunas (Hill 1939, Ripper 1938). Talent (1965) has suggested an Emsian age for this deposit. There is no direct indication as to the absolute time range of the Ruddock Siltstone and the formation may span a considerable interval.

Gill (1945, p. 145-6; 1965, p. 120) has recognized two successive brachiopod faunas within the Yering Group. An association of *Chonetes ruddockensis*, *Notanoplia australis*, *Plectodonta bipartita* and *Howellella* sp. apparently characterizes the lower part of the Ruddock Siltstone. The remainder of the Yering Group carries the association of *Chonetes cresswelli*, *C. robustus*, *C. micrus*, *Acrospirifer lily-*

dalensis and *Megakozłowskiella cooperi*. Gill (1945, p. 146) gives Ruddock's Quarry as the type locality for the lowest Yering Group fauna. Our species of *Acaste* and *Acastella* occurring together at that locality are therefore a part of that fauna. In terms of the NW. European stages Gill (1965, p. 121) has assessed the faunas of the Yering Group as a whole as comparable to those of the Gedinnian and Siegenian.

At an horizon slightly lower than that containing the 'Ruddock's Quarry fauna' Gill (1965, p. 120) has recorded the occurrence of *Styliolina fissurella* and *Nowakia matlockiensis* (= *arcuaria* ?). The presence of these elements has led Talent (1965, p. 183, Fig. 2) to correlate the lower Ruddock Siltstone with the Tanjil Formation of Central Victoria. On the basis of the tentaculitoid faunas, correlation has been further effected with strata falling within the graptolite zone of *Monograptus hercynicus* Jaeger (Lochkovian, e γ) in Bohemia. The formations thus related are quoted by Talent (1965, p. 183) as being no older than the Upper Gedinnian and most probably of Siegenian age. Jaeger (1966) in describing a new graptolite species, *M. thomasi*, from the Wilson's Creek Shales of Central Victoria, has discussed the age and correlation of these beds and the immediately overlying Tanjil Formation. His conclusions (1966, p. 397, Fig. 1) are essentially support for the ideas of Talent, i.e. that the Tanjil Formation is of probable Siegenian age. In this event the Ruddock's Quarry fauna becomes of similar age. No graptolites have yet been reported from the Ruddock Siltstone so that direct correlation on these grounds cannot be made with either the Wilson's Creek Shales or the Tanjil Formation. Correlation is effected solely with the aid of the tentaculitids.

In assessing the relationships of *Acaste longisulcata* sp. nov., comparison is indicated with *A. dayiana*, a species from the Lower Devonian (Shirley 1962) Köbbinghäuser Schichten of the German Rhineland, which beds are possibly of lowest Lower Gedinnian age. The Australian species of *Acastella*, existing contemporaneously with *Acaste longisulcata* in Victoria, has certain affinity to *Acastella patula*, from the Lower Oudai Hara Formation of SW. Morocco, of definite Lower Gedinnian age, and *A. rouaulti* which occurs in beds of Siegenian age. *A. frontosa* may be classified with the non-denticulate species-group of *Acastella* which ranges, in the northern hemisphere, to the top of the Lower Gedinnian (Sidi M-Bark Formation) in Morocco. The denticulate species-group extends a little higher, into the Siegenian. The absence of the denticulate forms of *Acastella* coupled with the presence of *Acaste* indicates that the Ruddock Siltstone at Ruddock's Quarry is older than the Siegenian, being probably of late Gedinnian age, though the remainder of the formation may range into the Siegenian. The absence of the *Acaste* at Wilson's and the Hull Road locality, horizons at stratigraphical levels above that at Ruddock's Quarry, may underline this point.

Acknowledgements

I must express my deepest gratitude to Mr E. D. Gill, National Museum of Victoria, for originally sending specimens to me through Dr J. Shirley, University of Newcastle upon Tyne, at a time when I was engaged in a study of the genus *Acaste* at that University, and then later on for entrusting me with an entire collection of recently obtained material. I am obliged to Mr T. A. Darragh, National Museum of Victoria, for arranging for me to borrow Chapman's type material and for supplying me with essential references to literature; and to Dr J. A. Talent for allowing me to examine specimens collected by Mrs K. L.

Reeves of Burwood and recently acquired by the Geological Survey of Victoria. I thank Mr E. D. Gill and Dr J. A. Talent for reading and criticizing this manuscript.

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Explanation of Plates

PLATE 3

Acastella frontosa, fig. 1-4

- Fig. 1-3—VNM P12679: holotype, internal mould dorsal exoskeleton, figured Chapman 1915, Pl. XV, fig. 14; fig. 1, dorsal view, $\times 4$; fig. 2, lateral view, $\times 4$; fig. 3, dorsal view pygidium showing widened pleural furrows, $\times 4$. Ruddock's Quarry, Lilydale.
- Fig. 4—GSV 61859: latex cast from external mould of cranidium, dorsal view, $\times 4$. Hull Road, Lilydale.

PLATE 4

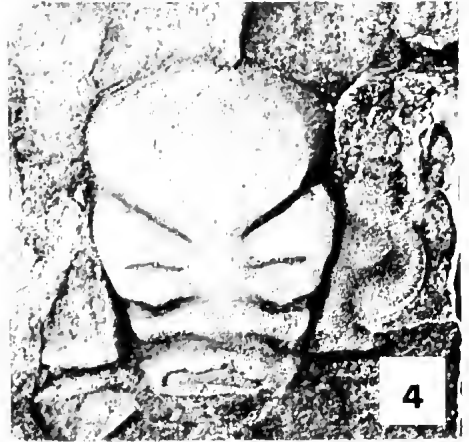
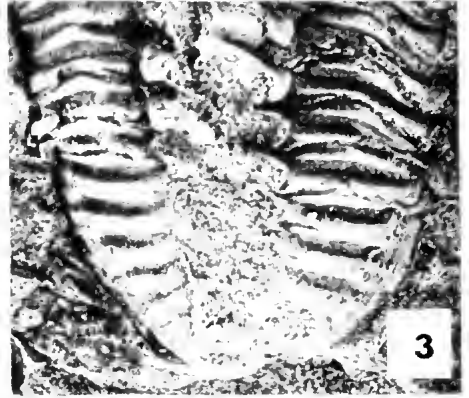
Acastella frontosa, fig. 1-6*Acaste longisulcata*, fig. 7-8

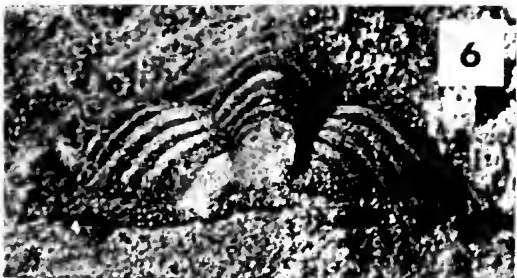
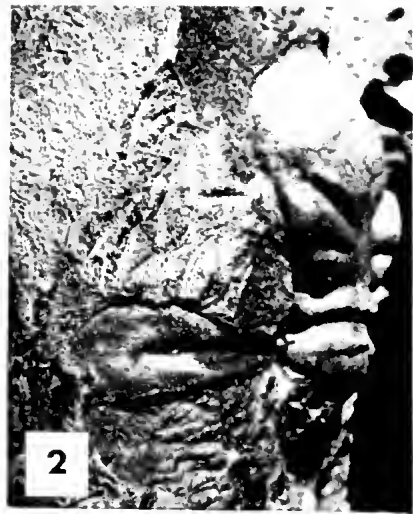
- Fig. 1-2—GSV 61859: internal mould of cranidium; fig. 1, dorsal view, $\times 4$, showing anterior cranial process; fig. 2, lateral view, $\times 4$, showing genal spine. Hull Road, Lilydale.
- Fig. 3-4—GSV 61860: latex cast from external mould of cephalon; fig. 3, dorsal view, $\times 4$, showing well-defined anterior angulation of the frontal lobe and the anterior cranial process; fig. 4, lateral view, $\times 4$, showing the genal spine and upturned frontal process. Hull Road, Lilydale.
- Fig. 5-6—GSV 61861: internal mould pygidium; fig. 5, dorsal view, $\times 6$, showing entire margins; fig. 6, posterior view, $\times 6$, showing convexity. Hull Road, Lilydale.
- Fig. 7-8—VNM P12680: holotype of *Acaste longisulcata*, internal mould pygidium, figured Chapman 1915, Pl. XV, fig. 15; fig. 7, dorsal view, $\times 4$; fig. 8, posterior view, $\times 4$. Ruddock's Quarry, Lilydale.

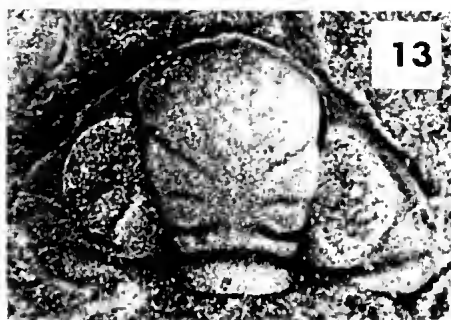
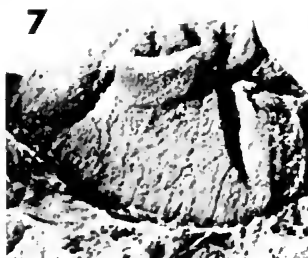
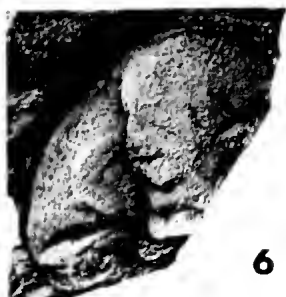
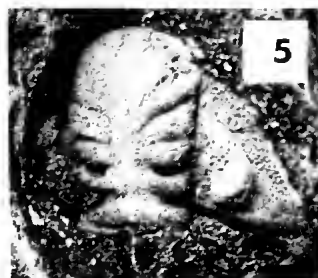
PLATE 5

Acaste longisulcata, fig. 1-12, all material from west of Black Springs, Lilydale.*Acaste* sp. fig. 13-14, Golden Grove, Llandeilo, Caermarthenshire, South Wales.

- Fig. 1-2—VNM P25230: two aspects of a well preserved cephalon; fig. 1, internal mould showing angled left gena, $\times 4$; fig. 2, latex cast from the external mould, $\times 4$.
- Fig. 3—VNM P25233: internal mould cephalon, early holaspis showing left genal spinule, $\times 6$.
- Fig. 4—VNM P25240: internal mould incomplete cephalon, distorted, $\times 4$.
- Fig. 5—VNM P25231: internal mould cephalon, $\times 4$.
- Fig. 6-7—VNM P25234: internal mould incomplete cephalon; fig. 6, dorsal view, $\times 4$; fig. 7, lateral view showing visual surface, $\times 4.5$.
- Fig. 8—VNM P25232: internal mould distorted cephalon, $\times 5$.
- Fig. 9—VNM P25235: internal mould pygidium, $\times 6$.
- Fig. 10—VNM P25236: latex cast from external counterpart of fig. 9, $\times 6$.
- Fig. 11—VNM P25238: internal mould pygidium, $\times 6$.
- Fig. 12—VNM P25237: latex cast from an external mould, $\times 6$.
- Fig. 13-14—GSM 19403: internal mould cephalon, figured Richter & Richter 1954, Pl. 3, fig. 44, included for comparison; fig. 13, dorsal view, $\times 4$, fig. 14, lateral view, $\times 4$.







LITTORAL AMPHIPODA OF VICTORIA

PART 1

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Abstract

A new genus of the Family Haustoriidae, a new species of *Urohaustorius*, and two new genera and species of the Family Oedicerotidae from Victoria, Australia, are described and figured.

Introduction

This paper describes four new Victorian Amphipoda, three of which have been observed in the euryhaline waters of Lake King (Gippsland), and one in the marine waters of Port Phillip Bay.

The work forms part of a comprehensive study of the ecological relationships of the Amphipoda of the major bays and inlets of the Victorian coastline. Other aspects of this study will be dealt with in subsequent papers.

Previous contributions to the taxonomy of the marine Amphipoda of South-Eastern Australia are scarce. Haswell (1882) made reference to the genera *Melita*, *Exoediceros*, *Talorchestia*, *Allorchestes*, *Aspidophoreia* and *Orchestia*, all of which he recorded off the New South Wales coast. Chilton (1923) recorded *Melita festiva* in Port Jackson; Whitelegge (1889) noted the presence of *Melita*, *Orchestia* and *Talorchestia* in Port Jackson and *Exoediceros fossor* in Botany Bay. Finally, Sheard (1936) referred to two species of *Urohaustorius* and to *Exoediceros maculosis* in Spencer Gulf, South Australia.

Thus it is evident that, apart from the work of Sayce (1901, 1902) and Williams (1962) on the freshwater Amphipoda of Victoria, there is a dearth of knowledge of this group, particularly of the southern Australian waters.

Family HAUSTORIIDAE

Genus *Urohaustorius* Sheard

Urohaustorius Sheard 1936, p. 445.

Type species by original designation: *Urohaustorius halei* (Sheard), 1936.

***Urohaustorius metungi* n. sp.**

(Fig. 1A-F, 2A-F, 3A-E)

DIFFERENTIAL DIAGNOSIS: To the author's knowledge, this is only the second reference to the genus *Urohaustorius* in Amphipod taxonomy. The form described below is undoubtedly closely related to those described by Sheard (1936), viz. *U. halei* and *U. vercoi*. The principal points of difference of the new form from these two species are as follows:

The third segment of the second antenna of the new form is about four times as long as the combined lengths of the first and second segments, and about one third of the length of the greatly expanded fourth segment. This third segment is relatively much larger than its counterpart in the earlier species of *Urohaustorius*.

In the second maxilla of the new form the outer plate is only a little wider than the inner plate whereas it is twice as wide in the other species.

Finally, the coxa of the fourth peraeopod in the new form differs somewhat from that of the earlier species in dimension and shape. In the species described hereunder this coxa is nearly as long as wide, whereas in *U. vercoi*, Sheard (1936) describes this feature as nearly as wide as long. In *U. halei* this coxa is 3 times as long as wide.

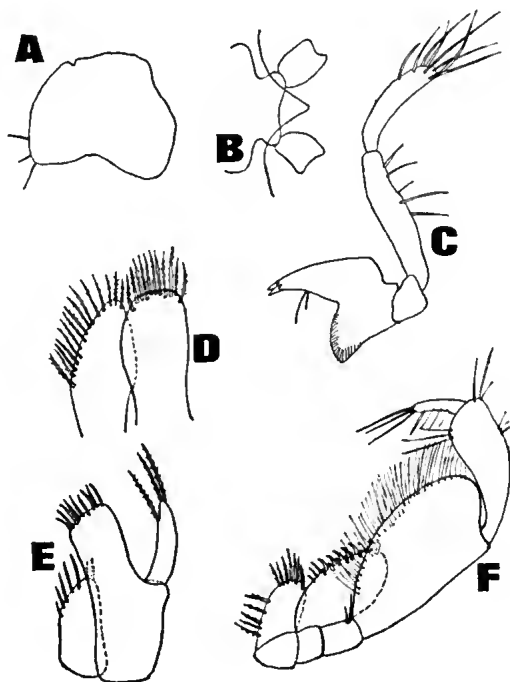


FIG. 1—*Urohaustorius metungi* (n. sp.). A. Coxa of peraeopod 4, c. \times 20. B. Bilobed projection of head (partly covered by rostrum), c. \times 20. C. Left mandible, c. \times 40. D. Maxilla 2, c. \times 75. E. Maxilla 1, c. \times 75. F. Maxilliped, c. \times 50.

DESCRIPTION OF MALE: Maximum body length recorded, 8.0 mm; for the sample of 11 specimens examined the mean length was 5.5 mm (S.D. = 1.3); depth of body about one quarter of the length of the body. Head short, broader than long. Rostrum small, sharply pointed. Eyes lateral, well developed, not pigmented.

Antenna 1—The recorded variation in length ranged from 2.5 mm to 0.8 mm with a mean of 1.5 mm (S.D. = 0.6) for the 11 specimens examined.

As in *U. halei* (Sheard 1936), the pair of first antennae jointed to a small two-branched process arising from the frontal margin of the head; first segment large, sub-rectangular, furnished with tufts of spines on inner and outer distal margins; second segment subovate, half as long and half as broad as first segment,

well equipped with long setose spines; third segment small with a few distal spines; flagellum with 8 segments, with tufts of spines at the distal margins of each segment; accessory flagellum three quarters of length of main flagellum, with tufts of spines at the distal margins of each segment.

Antenna 2—Larger than antenna 1; first and second segments very small; third segment about four times as long as combined length of first and second segments and about one third length of greatly expanded fourth segment; fourth segment subrectangular, heavily spined and possessing 10 very long setose spines radiating from convex outer margin; fifth segment half the dimensions of fourth segment, but rounded distally and with convex inner and outer margins, a row of long setose spines arising from the outer margin; flagellum with eight segments with tufts of small spines at the distal margins of each segment.

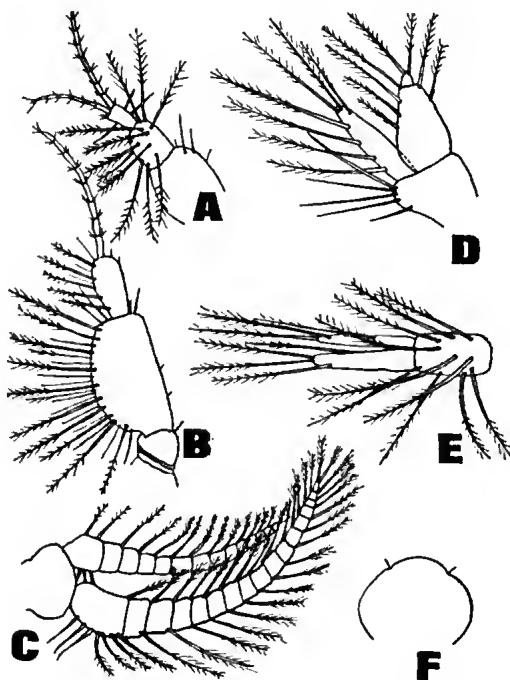


FIG. 2—*Urohaustorius metungi* (n. sp.), A. Antenna 1, c. $\times 20$. B. Antenna 2 (male), c. $\times 22$. C. Pleopod 1, c. $\times 20$. D. Uropod 3, c. $\times 35$. E. Uropod 1, c. $\times 22$. F. Telson, c. $\times 22$.

Mouth Parts—Upper lip minutely setose at apex of broadly rounded distal margin. Lower lip, inner lobes prominent, minutely setose; outer lobes more heavily setose distally. Mandibles, cutting edge with about 5 teeth; secondary process absent; spine row consisting of two simple spines; molar process heavily armoured; palp three-segmented; first segment as broad as long, devoid of spines; second segment long, subrectangular, with a few long spines on outer margin; third segment spatulate, three quarters length of second segment, furnished with long

spines distally and on inner margin. Maxilla 1, inner plate shorter and narrower than outer, tipped with short spines; outer plate heavily spined at truncated end; palp 1-segmented, terminating in three long setose spines. Maxilla 2, inner plate slightly shorter than outer, apical, with a distal cluster of setose spines; outer plate a little wider than inner with several rows of setose spines at the broadly rounded end. Maxillipeds, inner plate small, with several rows of large setose spines on rounded distal border, 4 or 5 very large setose spines on inner margin; outer plate subovate, reaching beyond the base of second palp segment, the long curved inner

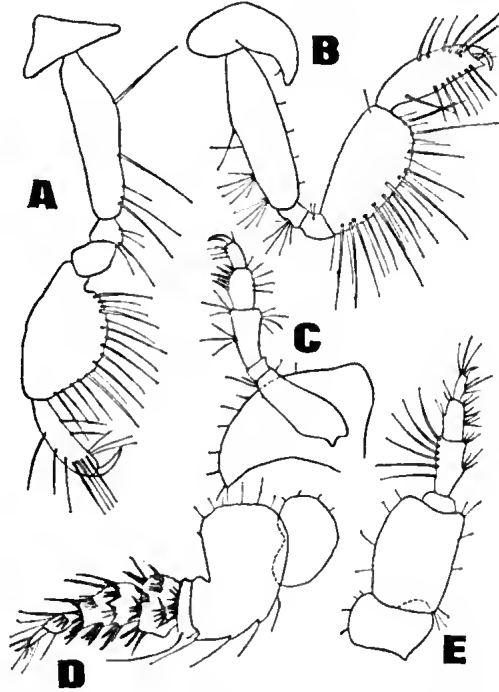


FIG. 3—*Urohaustorius metungi* (n. sp.) A. Gnathopod 1 (male), c. $\times 32$. B. Gnathopod 2 (male), c. $\times 22$. C. Peraeopod 1, c. $\times 15$. D. Peraeopod 3, c. $\times 15$. E. Peraeopod 4, c. $\times 10$.

margin furnished with several rows of heavy spines which lack setation; basos and ischium both small; palp consisting of four segments; the first segment nearly twice as long as ischium with one or two long spines just below the inner proximal angle of succeeding segment; the second segment the largest, broadly ovate, heavily fringed on inner convex surface with very long setae; the third segment broadening distally to form a club-shaped segment, tufts of long spines along inner distal and outer margins; the fourth segment tapering distally, about one third of length of third segment, inner margin lined with long simple spines, tipped with three very long simple spines.

Gnathopod 1—Segment 1 subtriangular, margins slightly concave, sparsely furnished with minute spines. Segment 2 elongate, somewhat constricted proximally,

length about four times maximum breadth; posterior surface has a few long setose spines. Segment 3 about as long as broad; a cluster of long spines on distal end of posterior margin. Segment 4 twice length of segment 3, subtriangular, posterior margin slightly convex. Segment 5 ovate, twice as long as broad, shorter but broader than segment 2; anterior margin devoid of setae or spines; posterior surface fairly heavily equipped with simple spines of varying lengths, many as long as breadth of segment 5. Segment 6, about two thirds length of segment 5; antero-distal margin has several fairly long spines; a row of long simple spines across the segment at distal two thirds. Palm straight, equipped with long spines. Segment 7, simple, spines absent.

Gnathopod 2—Larger than gnathopod 1. Segment 1 crescentic, basal margin concave, sparsely furnished with minute spines. Segment 2 elongate, subrectangular, length more than four times maximum width; a row of four short equally spaced spines along straight anterior margin, several clusters of long setose spines on distal half of broadly convex posterior margin. Segment 3 about as long as broad, long setose spines on distal end of posterior margin. Segment 4 slightly larger than segment 3, subovate, two tooth-like spines on anterior surface. Segment 5 subovate, slightly shorter and slightly broader than segment 2, anterior margin devoid of setae or spines except for one short spine in the antero-distal angle; posterior surface heavily spined with several rows of shorter spines and one row of about 12 very long spines. Segment 6, nearly as long as Segment 5, heavily spined on posterior surface, a row of long simple spines across segment at about one quarter of length from posterior end; postero-distal angle produced to form a stout tooth-like spine which bites with segment 7. Palm transverse, numerous small spines along edge. Segment 7, tip extending slightly beyond toothed spine of segment 6.

Peraeopod 1—Segment 1 large, subtriangular with broadly rounded anterior and posterior margins with slender spines on the postero-ventral margin. Segment 2, about two thirds length of segment 1, with several setose spines radiating from the postero-distal margin, a few smaller ones on anterior and posterior margins; length about three times maximum width. Segment 3 about as long as wide, a small group of simple spines postero-distally. Segment 4, length a little greater than twice the width; long spines at antero- and postero-distal angles, and on mid-posterior margin. Segment 5, ovate, length about twice the width, a row of long slender spines on anterior surface, five heavy spines and two slender simple spines on posterior surface. Segment 6, about two thirds length of segment 5, and about twice as long as wide; eight heavy spines on postero-distal margin, with numerous minute spines at their bases. Segment 7 sharp, slightly curved, more than half of the length of segment 6; a minute slender spine proximally.

Peraeopod 2—Segment 1 nearly as wide as long. Segment 2, one and a quarter times the length of the segment 1, with several long setose spines distally. Otherwise very similar to *peraeopod 1*.

Peraeopod 3—Segment 1 small, feebly bilobed, the lobes subequal, the posterior lobe equipped with a few simple marginal spines. Segment 2, the largest segment, greatly expanded to produce a subrectangular lobe posteriorly; a few long slender spines on curved anterior surface; a row of simple spines on the posterior margin of the expanded lobe. Segment 3, four times as broad as long, with a long spine at antero-distal angle, and heavily spined along distal edge. Segment 4, subrectangular, twice as broad as long, heavily spined over the whole segment. Segment 5 one and one half times as long as broad, tapering and elaborately furnished with several clusters of downwardly directed strong spines. Segment 6 narrow proximally,

expanding to maximum breadth of about half length of segment, similar in spination to segment 5. Segment 7, subovate, shorter and about one third as broad as segment 6, furnished with three strong spines distally.

Peraeopod 4—Segment 1 small, feebly bilobed, sparsely spined on posterior margin. Segment 2, subovate, as broad as segment 1 and twice as long as its depth, minutely produced antero-distally with two long spines in antero-distal angle; minutely spined around margin. Segment 3, small, sub-trapezoidal, devoid of spines. Segment 4 slightly broadened distally, slightly produced at postero-distal angle; clusters of fairly heavy spines on mid-anterior and antero-distal surfaces; posterior surface has elongate setose spines. Segment 5, subrectangular, furnished with clusters of very heavy spines on anterior and posterior surfaces. Segment 6, subrectangular, half dimensions of segment 5, heavily spined on anterior and distal surfaces. Segment 7, reduced to a massive tooth-like spine.

Peraeopod 5—Similar to peraeopod 4, but slightly smaller.

Pleopods—All alike, biramous, rami similar and much longer than peduncle; inner ramus somewhat shorter than outer, about 14 distinct segments compared with about 18 in outer ramus. Each segment has an inner and outer long setose spine at about midway, which is a peculiarly refractive region (Williams 1962).

Uropod 1—Rami subequal in length, slightly longer than peduncle. Outer ramus with 3 or 4 elongate setose spines borne terminally. Inner ramus with 1 or 2 elongate spines borne terminally. Peduncle about twice as long as broad, with row of very long spines on inner margin, an arc of 6 stout setose spines in horseshoe formation on dorsal surface.

Uropod 2—Like uropod 1. Outer ramus slightly longer and broader than inner. Peduncle about twice as long as broad. Spination almost identical with that of uropod 1.

Uropod 3—Rami subequal in length, outer much broader and two-segmented. Inner ramus with long setose spines distally and on inner margin. Outer ramus, basal segment with long setose spines distally and on inner margin, terminal segment with two long setose spines distally. Peduncle broader than long, proximally constricted; a cluster of simple spines of varying lengths at the inner-distal angle.

Telson—Entire, subcircular, two simple spines on distal margin.

Branchiostegites—Simple sac-like structures.

DESCRIPTION OF FEMALE: Maximum body length recorded, 7.5 mm; smaller than males of corresponding age. Apart from oostegites, females are morphologically similar to males except for slightly heavier spination and setation of males.

Oostegites—Thinly elongate, furnished with very long simple spines.

Colour—White, lacking pigment markings.

TYPES: *Locality*—The holotype is a male specimen from a collection made at Tambo Bay in the south-eastern corner of Lake King in September 1957.

Repository—The holotype (No. J.151) and paratypes (No. J. 152) are lodged at the Museum of Natural History, Melbourne, Australia.

VARIATION IN MATERIAL EXAMINED: Eleven specimens were dissected, four of which were males. The male forms varied in length from 8.0 mm to 4.5 mm, the females from 6.0 mm to 3.4 mm. In the sample examined variation in the length of the body and of the individual appendages is well marked, reaching a maximum in the fourth peraeopod with a mean length of 3.4 mm (S.D. = 0.7).

DISTRIBUTION: Present Records: *Victoria*: Lake King (September 1957). The distribution of *U. metungi* is indicated in Fig. 17. It will be observed from the available evidence that this species is restricted in its distribution to Tambo Bay, a shallow bay near the township of Metung from which the specific name of the animal has been derived.

ECOLOGICAL NOTES: The species was recorded in association with *Limnoporeia kingi* (n. sp.). It is a very efficient burrower in the fine sands of this bay.

KEY TO SPECIES OF GENUS *Urohaustorius*

1. Third segment of antenna 2 about four times as long as the combined length of the first and second segments *U. metungi* (n. sp.)
1. Third segment of antenna 2 about twice as long as the combined length of the first and second segments 2
2. Segment 1 of pereopod 4 as wide as long *U. vercoi*
2. Segment 1 of pereopod 4 at least three times as long as wide *U. halei*

ANATOMICAL STATISTICS OF *Urohaustorius metungi* (n. sp.)

Characteristic	Maximum (mm)	Minimum (mm)	Mean (mm)	Standard Deviation	Length of appendage/body length ratio
Body length (Rostrum to telson)	8.0	3.4	5.5	1.3	1.0
Antenna 1	2.5	0.8	1.5	0.6	0.3
" 2	3.0	1.0	2.0	0.7	0.4
Gnathopod 1	2.8	1.3	2.0	0.5	0.4
" 2 ♂	3.5	2.5	3.0	0.6	0.6
" 2 ♀	3.0	1.8	2.2	0.6	0.4
Pereopod 1	3.5	1.8	2.3	0.6	0.4
" 2	3.5	1.5	2.5	0.5	0.5
" 3	4.3	1.8	3.0	0.8	0.5
" 4	4.8	2.5	3.4	0.7	0.6
" 5	3.8	2.0	2.8	0.6	0.5
Pleopod 1	2.3	1.3	1.8	0.3	0.3
Uropod 1	1.5	0.8	1.0	0.3	0.2
" 2	1.5	0.5	0.9	0.3	0.2
" 3	1.0	0.3	0.6	0.3	0.1

Genus *Limnoporeia* (n.g.)

Type species: *Limnoporeia kingi* (n. sp.)

DEFINITION OF THE GENUS LIMNOPOREIA: Animal with a broadly rounded back. Head small with a pronounced rostrum projecting well forward. Eyes moderately large, lateral, heavily pigmented.

Antenna 1, first peduncular segment with a pronounced projection anteriorly, accessory flagellum well defined.

Antenna 2, about twice as long as antenna 1 in male, fourth peduncular segment very large.

Mandibles with cutting edge, molar process and spine row greatly reduced.

Maxillipeds with large four-segmented palp but with small inner and outer plates, the outer plate just reaching beyond the base of the second segment of the palp. Mouthparts otherwise normal as in the family *Haustoriidae*.

Gnathopods, in both sexes, chelate, with relatively large curved chelae and segments.

Peraeopod 4 the largest appendage, about one and one half times as long as other peraeopods. Segments of peraeopods not greatly expanded, except second segment of peraeopods 4 and 5.

Pleopods typical of the Family *Haustoriidae*.

Outer ramus of third uropod long, two-segmented.

Inner ramus less than one third of the outer.

Telson cleft to the base.

Coxal plates relatively deep on gnathopods 1 and 2 and peraeopods 1 and 2, but relatively shallower in remaining peraeopods.

DIFFERENTIAL DIAGNOSIS: This form bears some resemblance to the genus *Amphiporeia* (Shoemaker 1929), although the presence of a distinctive rostrum and a three-segmented accessory flagellum on antenna 1 excludes it from this genus. There is, however, a closer resemblance between this form and the genus *Pontoporeia* (Krøyer 1842) within the Family *Haustoriidae*, but there are significant differences. The outer ramus of uropod 3 is relatively long, not short as in *Pontoporeia*; in gnathopod 1 the sixth segment is longer than the fifth, and the latter is not expanded as in *Pontoporeia*. Further, the rostrum is distinctly elongated and hooded, covering the first segment of the peduncle of antenna 1. In this latter feature the new genus resembles *Platyischnopus*, but there are several distinguishing differences. These are the deep coxal plates of gnathopods 1 and 2 and peraeopods 1 to 3, the deeply cleft telson, the third and fourth segments of fourth and fifth peraeopods not greatly expanded, the fourth segment of gnathopods 1 and 2 not elongated, outer plate of maxilliped not reaching beyond second segment of palp as in *Platyischnopus*. Another feature of interest is the short process projecting anteriorly from the first peduncular segment of antenna 1 over the second peduncular segment.

***Limnoporeia kingi* (n. sp.)**

(Fig. 4A-C; 5A-G; 6A-D; 7A-D)

DESCRIPTION OF FEMALE: Maximum body length recorded, 3.5 mm; eyes moderately large, lateral, heavily pigmented. Animal transparent apart from eyes. Rostrum relatively large, projecting well forward like a hood over the first and second segments of the peduncle of antenna 1.

Antenna 1—The recorded variation in length ranged from 0.75 to 0.50 mm with a mean of 0.60 mm (S.D. = 0.10) for the six specimens examined, five of which were female. Flagellum four to five segmented, the segments longer than wide, each with a circlet of setae distally. Accessory flagellum three to four segmented like primary flagellum, but shorter. Peduncle, first segment largest, with an anteriorly projecting process bearing a tuft of spines at its extremity, second segment two thirds length of first, third segment as long as but only half as broad as second, all segments heavily spined.

Antenna 2—In male about twice as long as antenna 1—equipped with numerous long spines; fourth peduncular segment the largest. Flagellum 9-10 segmented in male, 4-5 segmented in female, each segment with setae at the distal angles.

Mouth Parts—Upper lip, rounded and entire, setose distally. Lower lip, inner and outer lobes subovate, distal and inner margins setose. Mandibles, cutting edge lightly toothed; secondary process tricuspid in appearance; molar process and spine

row greatly reduced; palp, 3-segmented; first segment short; second segment twice the length of first, bearing one stout spine; third segment two thirds length of second, equipped with 7 or 8 elongate spines apically. Maxilla 1, inner plate short, subovate, lacking spination and setation; outer plate subrectangular, heavily spined apically, palp slender, one-segmented, tipped with three or four simple spines. Maxilla 2, inner plate broader but a little shorter than outer plate, each plate with a group of spines apically. Maxillipeds, inner plate small, subrectangular, with two large spines at distal border; inner and outer margins devoid of spines; outer plate relatively small, narrow, rounded distally, bearing three stout spines on the inner margin distally; palp large, four-segmented; first segment subtrapezoidal; second

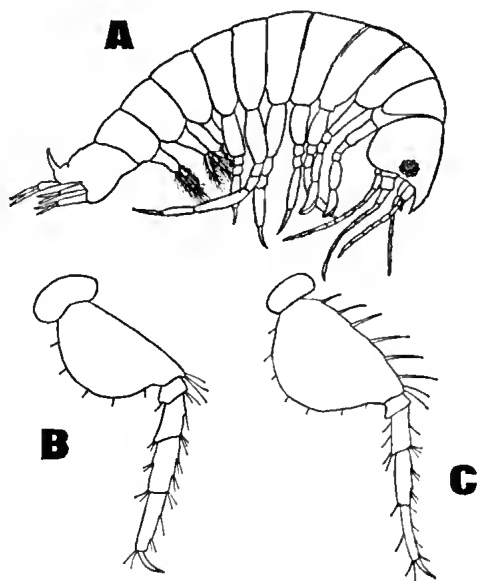


FIG. 4—*Limnoporeia kingi* (n. sp.). A. Complete female specimen, c. $\times 25$. B. Peraeopod 3, c. $\times 30$. C. Peraeopod 5, c. $\times 45$.

segment ovate, the largest, heavily spined on the convex inner margin; third segment subovate, half length of second; fourth segment small, tapering distally, bearing a heavy spine at its extremity.

Gnathopod 1—Chelate. Segment 1 subrectangular, depth about 1.5 times maximum width; anterior margin slightly concave; distal margin has a tuft of minute spines in the middle, a row of five heavy spines arranged along the postero-distal margin. Segment 2 somewhat constricted proximally, maximum width about one quarter of the length; a single elongate spine on the mid-posterior margin; a single minute spine in each of the antero-distal and postero-distal angles. Segment 3 longer than wide, a single spine on the postero-distal margin. Segment 4 subtrapezoidal, slightly longer than segment 3, a single spine near the postero-distal angle. Segment 5 sub-triangular, with a pair of spines medially on posterior margin. Segment 6 as long as segment 2 and wider, slightly curved with broadly convex anterior margin and concave posterior margin, tapering to a finely toothed tip, lightly spined along the distal margins. Palm oblique, slightly convex, extending

along more than one third of the anterior margin of segment 6, with numerous small simple spines along edge; two teeth at the distal end. Segment 7 almost as long as the palm; a small spine about half way along outer margin.

Gnathopod 2—Chelate. Segment 1 subrectangular, depth about twice the width; posterior margin almost straight; two large simple spines in the postero-distal angle. Segment 2 constricted proximally, as long as segment 1, maximum width about one third of length; a few simple spines on margins. Segment 3 slightly longer than broad, subrectangular. Segment 4 longer than segment 3, spines rare. Segment 5

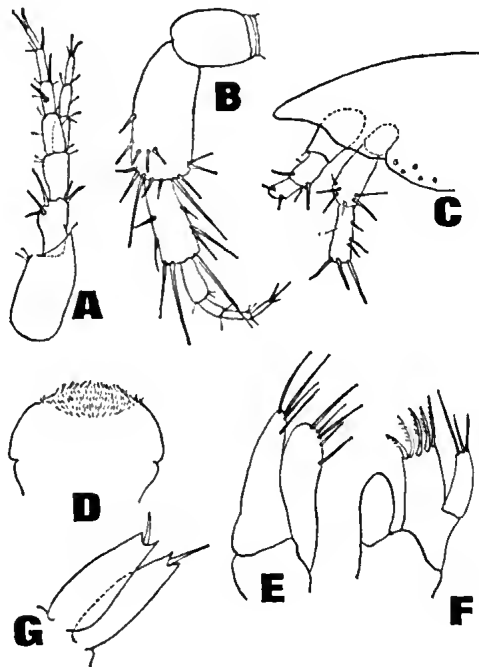


FIG. 5—*Limnoporeia kingi* (n. sp.). A. Antenna 1, c. $\times 65$. B. Antenna 2 (female), c. $\times 65$. C. Lateral view of rostrum showing peduncles of first and second antenna, c. $\times 50$. D. Upper lip, c. $\times 150$. E. Maxilla 2, c. $\times 75$. F. Maxilla 1, c. $\times 75$. G. Telson, c. $\times 75$.

slightly longer than segment 4, a few simple spines posteriorly. Segment 6 large, broader than segment 6 of gnathopod 1, but of same length and general shape. Palm oblique, slightly convex, extending along nearly half of the anterior margin of segment 6, with numerous spines of variable length. Two powerful teeth at the distal end of palm. Segment 7 elegantly curved, slightly longer palm; a small spine about half way along outer margin.

Peraeopod 1—Segment 1 subrectangular, anterior and posterior margins and distal margin almost straight; a row of four simple spines at the postero-distal angle. Segment 2 as long as segment 1, slightly narrower proximally than distally, with several long simple spines on the postero-distal margin, a few smaller ones

anteriorly; length about three times maximum width. Segment 3 about as long as wide, a slender spine in the postero-distal angle. Segment 4 length more than twice its width; the antero-distal angle produced distally; spined on the posterior margin. Segment 5 subovate, length about twice the width, spined on posterior and postero-distal margins. Segment 6, three quarters the length of segment 5, but more slender, spined on posterior and postero-distal margins. Segment 7, sharp, acutely curved, less than half as long as propod.

Peraeopod 2—Segment 1 as deep as wide, produced slightly at the postero-proximal angle, anterior and distal margins almost straight. Otherwise very similar to peraeopod 1.

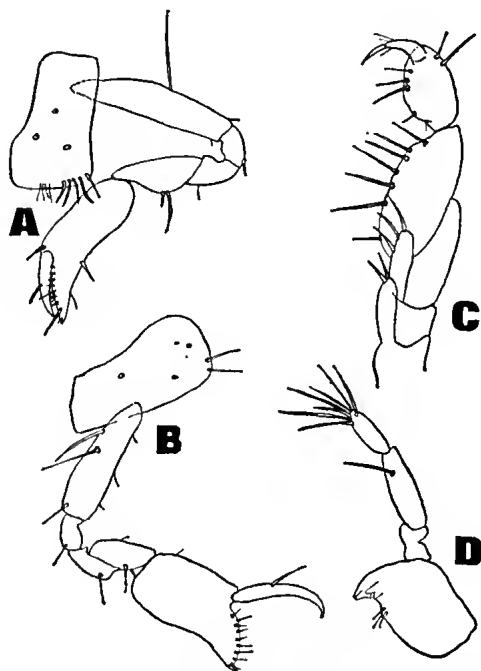


FIG. 6—*Limnoporeia kingi* (n. sp.). A. Gnathopod 1 (female), c. $\times 55$. B. Gnathopod 2 (female), c. $\times 50$. C. Maxillipeds, c. $\times 50$. D. Right mandible, c. $\times 50$.

Peraeopod 3—Segment 1 bilobed, posterior lobe larger than anterior. Segment 2 greatly expanded posteriorly; three long slender spines antero-distally; minutely spined posteriorly. Segment 3 subtrapezoidal, broader than long, with a tuft of spines at the antero-distal angle. Segment 4 widening distally, spined along anterior margin and in the postero-distal angle. Segment 5 subrectangular; about one and one half times as long as wide; spined on both anterior and posterior margins. Segment 6, about as long as segment 5, but about half its width; spined on anterior and posterior margins and at distal angles. Segment 7, only slightly curved.

Peraeopod 4—the longest, about one and one half times the length of other peraeopods. Segment 1 small, slightly expanded posteriorly, minutely spined.

Segment 2 greatly expanded, the anterior and antero-distal surfaces heavily spined. Segment 3 subtrapezoidal, spined on anterior surface. Segment 4 slightly constricted proximally; produced slightly in the postero-distal angle; spined along both anterior and posterior margins. Segment 5 subrectangular, clusters of spines at regular intervals along anterior margin. Segment 6 as long as segment 5, but only about half its width. Segment 7 only slightly curved.

Peraeopod 5—About two thirds length of peraeopod 4. Segment 1, smaller than that of peraeopod 4; subovate. Segment 2, enormously produced posteriorly. Otherwise like peraeopod 4.

Pleopods—All alike and unmodified. Biramous, rami similar and longer than peduncle; inner ramus slightly shorter than outer, of about 6 distinct segments as compared with about 8 in the outer ramus. Each segment has an inner and outer long spine.

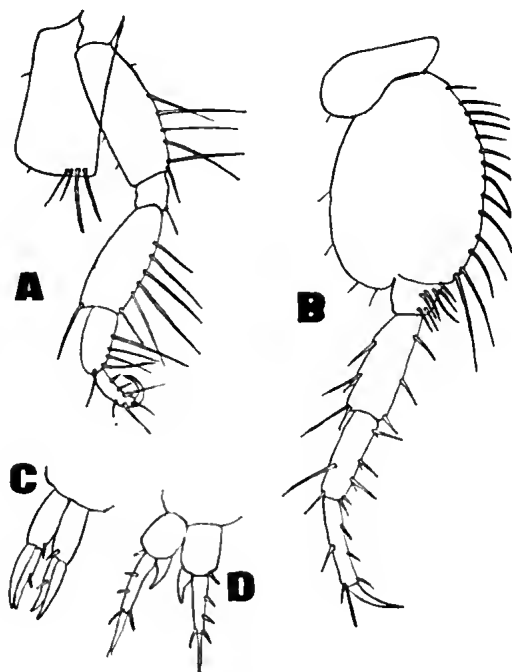


FIG. 7—*Limnoporeia kingi* (n. sp.). A. Peraeopod 1, c. $\times 40$. B. Peraeopod 4, c. $\times 45$. C. Uropod 1, c. $\times 20$. D. Uropod 3, c. $\times 35$.

Uropod 1—Rami subequal in length and as long as peduncle. Outer ramus, devoid of spines. Inner ramus bears a single stout spine about half way along inner margin. Peduncle elongate, subrectangular, with a stout spine at the distal end near base of inner ramus.

Uropod 2—The smallest, extending only as far as first segment of the outer ramus of the third uropod. Rami subequal in length. Outer ramus slightly longer than inner, devoid of spines and setae. Peduncle subrectangular, with two stout spines at the distal end near the bases of the rami.

Uropod 3—Shorter than first. Outer ramus large, two segmented with strong spines on outer margin of first segment; second segment two thirds the length of the first segment, with two slender spines at tip. Inner ramus one half length of outer, devoid of spines, a small seta at tip. Peduncle, subrectangular, much broader than peduncles of uropods 1 and 2, with a stout spine at the distal end near base of outer ramus.

Telson—Relatively large, approximately half the length of the third uropod; cleft to the base, each lobe tipped with a heavy spine.

Gills—Simple sac-like structures.

Oostegites—Elongate, subrectangular, with distal end rounded and equipped with long spine-like projections.

DESCRIPTION OF MALE: Body length 4.0 mm (only one specimen available for examination). Gnathopods somewhat larger than those of female. Otherwise similar in structure to female.

TYPES: *Locality*—The holotype is one of a collection made in Jones' Bay, Lake King, Victoria, Australia in May 1957.

Repository—The holotype (No. J.153) and paratypes (No. J.154) are lodged at the Museum of Natural History, Melbourne, Australia.

VARIATION IN MATERIAL EXAMINED: Six specimens were available for examination, five of which were female. These specimens varied in length from 4.0 to 2.5 mm with a mean of 3.0.

The uropods show the greatest degree of variability with respect to length. For example, the third uropod showed a standard deviation of 0.3 with a mean length of 0.6 mm in the specimens examined.

DISTRIBUTION: Present records: *Victoria*: Lake King (March 1957). As indicated in Fig. 17, *Limnoporeia kingi* has been recorded as widely distributed throughout Jones' Bay as well as the main body of Lake King.

ECOLOGICAL NOTES: The species is associated in its distribution with *Paroediceropsis raymondi* (n. sp.).

ANATOMICAL STATISTICS OF *Limnoporeia kingii* (n. sp.)

Characteristic	Maximum (mm)	Minimum (mm)	Mean (mm)	Standard Deviation	Length of appendage/body length ratio
Body length (Rostrum to telson)	4.0	2.5	3.0	0.3	—
Antenna 1	0.75	0.5	0.6	0.1	0.2
" 2 ♂	1.50	—	—	—	0.4
" 2 ♀	1.0	0.75	0.8	0.1	0.3
Gnathopod 1	1.5	1.0	1.2	0.2	0.4
" 2 ♂	2.0	—	—	—	—
" 2 ♀	1.75	1.0	1.3	0.2	0.4
Peraeopod 1	1.5	1.0	1.3	0.2	0.4
" 2	1.5	1.0	1.3	0.2	0.4
" 3	1.75	1.25	1.4	0.2	0.5
" 4	2.25	1.5	1.7	0.3	0.6
" 5	1.5	1.0	1.1	0.2	0.4
Uropod 1	1.25	0.5	0.8	0.3	0.3
" 2	0.75	0.25	0.5	0.2	0.2
" 3	1.0	0.25	0.6	0.3	0.2
Pleopod 1	1.25	0.75	0.9	0.2	0.3

Family OEDICEROTIDAE

Genus *Amphoediceros* (n.g.)Type species: *Amphoediceros willisi* (n. sp.)

DEFINITION OF THE GENUS *Amphoediceros*: Animal with broadly rounded back. Head small with minute, bluntly pointed rostrum. Eyes reniform and convergent.

Maxillipeds and maxillae well developed; the inner and outer plates of maxillae liberally spined. Mandibles with strongly denticulate molar process and well developed three-segmented palp.

Antennae long and slender; accessory flagellum of the first antenna reduced to a minute one-segmented process.

Gnathopods subchelate. All pereopods with well developed dactyls. Segment 1 of pereopod 3 is bilobed posteriorly.

All uropod rami taper distally. Telson deeply cleft.

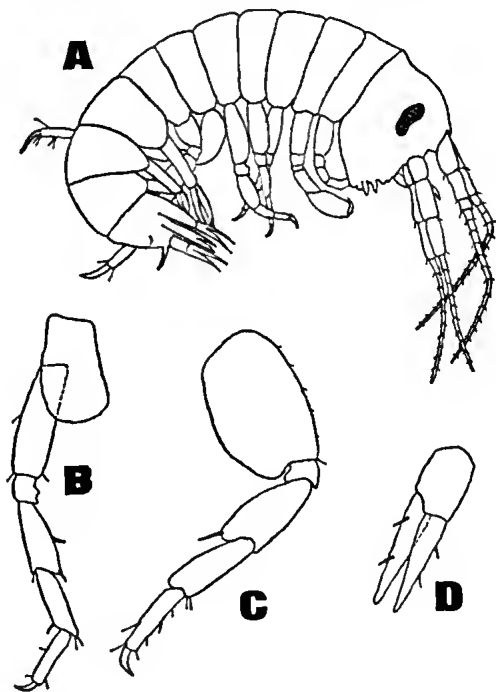


FIG. 8—*Amphoediceros willisi* (n. sp.). A. Complete female specimen, c. $\times 27$. B. Pereopod 1, c. $\times 30$. C. Pereopod 3, c. $\times 35$. D. Uropod 3, c. $\times 37$.

DIFFERENTIAL DIAGNOSIS: This new genus possesses most of the family characteristics of the Oedicerotidae, including a rudimentary accessory flagellum to the first antenna, contiguous eyes, an elongated fifth pereopod and a large mandibular palp.

Stebbing (1906), in his diagnosis of the family Oedicerotidae, describes the telson as small and entire. Several genera have been added to the family since Stebbing's work was published and, of these, two forms display a deeply emarginate

telson. These are *Methalimедon nordenskjoldi* (Schellenberg 1931) and *Paroediceroides sinuata* (Schellenberg 1931). In the genus described here the telson is quite elongate and deeply cleft. Thus it would seem that this tendency towards the division of the telson should be included in the family diagnosis.

In having a cleft telson, the new genus shows some similarity to *Methalimедon* and *Paroediceroides*, in both of which the telson is deeply emarginate. However, many other differences separate it from these genera. The closest genus appears to be *Exoediceros* (Stebbing 1899), with the following major differences: In *Exoediceros*, the telson is entire and as broad as it is long, whereas in the new genus this character is deeply cleft and elongate. In *Exoediceros*, the first and second pereopods lack dactyls, while those of the third and fourth pereopods are minute. In the new genus the dactyls are well developed on all of the pereopods. The inner plate of the first maxilla of *Exoediceros* is setose, while in the new genus it is spined. In *Exoediceros*, finally, the rami of the third uropod are truncated apically, but in the new genus each ramus tapers to a fine point distally.

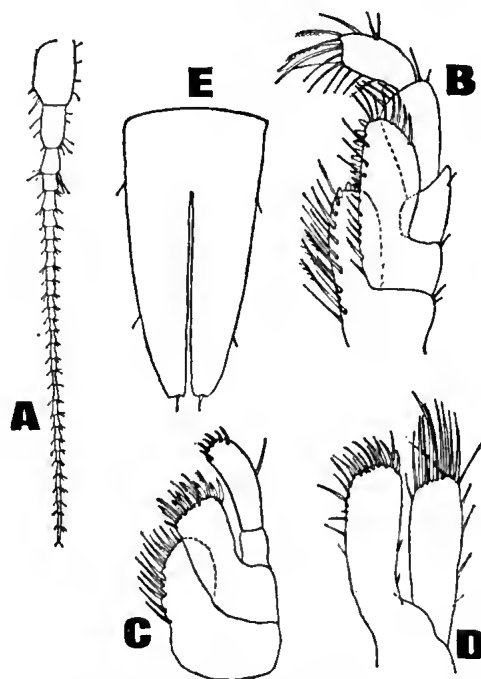


FIG. 9—*Amphoediceros willisi* (n. sp.). A. Antenna 1, c. $\times 20$. B. Maxillipeds, c. $\times 25$. C. Maxilla 1, c. $\times 40$. D. Maxilla 2, c. $\times 40$. E. Telson, c. $\times 20$.

Amphoediceros willisi (n. sp.)

(Fig. 8A-D; 9A-E; 10A-F; 11A-D)

DESCRIPTION OF MALE: Maximum recorded body length 4.3 mm; for the sample population of fourteen specimens which were examined, the mean body length was 4.1 mm (S.D. = 0.2); depth of the body about one quarter the length of the body. Eyes, reniform, convergent, darkly pigmented, about half maximum

depth of the head, enveloping the base of the first antenna. Rostrum bluntly pointed and minute.

Antenna 1—Flagellum up to about 40 small segments, the proximal segments generally broader than long, and the distal segments longer than broad, each with tufts of slender spines in the distal angles. Peduncle, the first segment the largest and broadest, the second about three quarters of the dimensions of the first, the third one half the length and three quarters the breadth of the second segment;

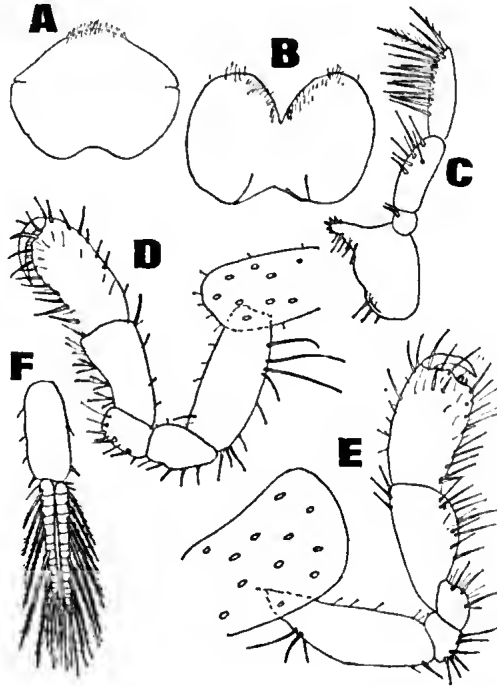


FIG. 10—*Amphoediceros willisi* (n. sp.). A. Upper lip, c. \times 150. B. Lower lip, c. \times 150. C. Left mandible, c. \times 100. D. Gnathopod 1 (male), c. \times 70. E. Gnathopod 2 (male), c. \times 70. F. Pleopod 1, c. \times 25.

the first segment with a few slender spines of varying lengths along the margins; the second and third segments with tufts of spines at the distal angles as well as variable spines scattered along the margins. Accessory flagellum greatly reduced, consisting of a minute one-segmented process tipped with two long spines.

Antenna 2—Flagellum up to 35 segments, structure similar to that of antenna 1, but lacking accessory flagellum. Peduncle, segments subequal in length but progressively narrower; third segment considerably narrower than that of antenna 1; all segments more heavily spined than in antenna 1.

Mouth Parts—Upper lip entire, setose distally. Lower lip, inner lobes absent; principal lobes subovate, distal margins setose. Mandible, cutting edge a small six-toothed process; secondary process tricuspid in appearance; molar process strongly denticulate, several setose spines proximally. Palp, first segment, subrectangular

with a long spine at the outer distal angle; second segment long, bearing long spines on inner margin; third segment as long as second, broadly convex on outer margin, bearing long spines on inner and distal margins. Maxilla 1, inner plate subovate, a row of long simple spines on convex inner surface; outer plate as long as inner, a cluster of heavily combed and toothed spines at truncated distal border; palp two-segmented, the first segment short subrectangular, the second long and curved, a single long spine on outer margin, a cluster of short heavy spines on distal margin. Maxilla 2, inner plate subequal with outer, and with a distal cluster of spines, outer margin furnished with long setae; outer plate subrectangular, distal margin flatly convex and with a cluster of long inwardly curved spines, outer distal margin with a few long fine setae. Maxillipeds, inner plate subrectangular, outer margin convex, inner margin lined with large setose spines, heavily spined on truncated distal border, three of these spines modified as well defined teeth; outer plate semi-circular reaching nearly to end of second segment of palp, distal region of outer margin bearing about seven long simple spines, inner distal margin strongly toothed, proximo-distal margin bearing long simple spines; palp four-segmented; first segment distal margin oblique, two small simple spines at outer distal angle; second segment, one and one half times the length of first, broadly ovate, a few simple spines on outer margin and at outer distal angle, a row of long simple spines lining the entire inner margin; third segment half the width of the second, copiously spined; fourth segment half the length of the third, tipped with several spines.

Gnathopod 1—Subchelate. Segment 1 subrectangular, broadly rounded distally, depth about one and one half times breadth; distal margin minutely spined. Segment 2 constricted proximally, maximum breadth less than half length; a few simple short spines on anterior margin; long spines on mid-posterior margin and at postero-distal angle. Segment 3 slightly longer than broad; spined along posterior margin. Segment 4 slightly smaller than segment 3, subrectangular; a row of long spines on postero-distal surface. Segment 5 widening distally; heavily endowed along posterior margin with long setose spines, a few long simple spines also along this surface. Segment 6, subrectangular, one and one quarter times the length of segment 5, fairly profusely spined on all surfaces; palm convex, bearing two rows of tooth-like spines, and many simple spines along its length. Segment 7, a little longer than palm; a small spine on outer margin about one third distance from base.

Gnathopod 2—Subchelate; as long as, and similar to gnathopod 1. Segment 1 subrectangular with broadly rounded distal margin, the latter minutely spined. Segment 2, like that of gnathopod 1, but with a group of four spines at the antero-distal angle in addition. Segment 3, twice as long as broad; a cluster of small simple spines about one quarter way along posterior margin from base. Segment 4, subrectangular, a row of eight long simple spines along distal margin. Segment 5 as in gnathopod 1. Segment 6 slightly longer than segment 5, subrectangular; rows of long simple spines regularly spaced along anterior surface; posterior surface similarly equipped, but with much heavier spines; palm, flatly convex, with many simple spines and a few heavy tooth-like spines along its length. Segment 7, tip slightly short of the end of palm; a simple spine on outer margin near base.

Peraeopod 1—Segment 1 subrectangular with a rounded dissection at the antero-proximal angle, minutely setose along entire margin. Segment 2 as long as side-plate is broad, subrectangular, minutely curved, several long simple spines on anterior and posterior surfaces, a pair of such spines in each of the postero-distal and antero-distal angles; length about four times maximum width. Segment 3

slightly broader than long, a pair of simple spines in the antero-distal angle. Segment 4, length about twice maximum width and about three times length of segment 3, several spines on anterior margin, a single spine on the mid-posterior margin; postero-distal angle slightly produced along posterior surface of segment 5, a cluster of spines at this angle. Segment 5, subrectangular, as long as segment 4, anterior surface with a row of simple spines. Segment 6, slightly longer than segment 5 but narrower, rectangular, similarly spined to segment 5. Segment 7, curved and sharply pointed, a stout spine near base, bearing several spines near tip.

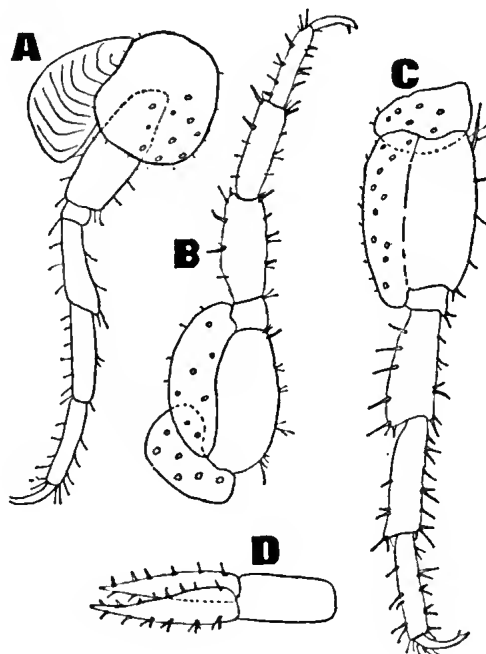


FIG. 11—*Amphoedicerus willisi* (n. sp.). A. Peraeopod 2 (with side plate and gill attached), c. $\times 45$. B. Peraeopod 4, c. $\times 40$. C. Peraeopod 5, c. $\times 37$. D. Uropod 2, c. $\times 60$.

Peraeopod 2—Segment 1 almost circular, minutely setose; Segment 2 as long as segment 1 but one third its width. In other respects identical with peraeopod 1.

Peraeopod 3—Segment 1 bilobed posteriorly. Segment 2 subovate, posteriorly expanded, posterior margin setose, pairs of short stout spines at regular intervals along anterior surface, a group of such spines antero-distally. Segment 3, slightly broader than long, antero-distal angle with a cluster of stout spines. Segment 4, length about two and one half times maximum breadth, clusters of spines along anterior and posterior surfaces, some of the spines being bifurcated, postero-distal angle slightly produced along length of segment 5. Segment 5 heavily spined along anterior and posterior surfaces as in segment 4, posterior angle also produced slightly. Segment 6, subrectangular, slightly shorter and narrower than segment 5, with clusters of bifurcate spines along both anterior and posterior surfaces. Segment 7 as in peraeopods 1 and 2.

Peraeopod 4—Segment 1 subovate, greatly expanded posteriorly, minutely setose. Otherwise similar to peraeopod 3.

Peraeopod 5—Segment 1 smaller than that of peraeopod 4, ovate, minutely setose. Peraeopod 5 greatly elongated attaining a mean length of 2.1 mm (S.D. = 0.1) for the 14 specimens examined. Similar to peraeopods 3 and 4 except that postero-distal angle of segment 4 is more definitely produced distally; all segments more heavily spined than in previous appendages.

Pleopods—All alike and unmodified; biramous; rami similar and longer than peduncle; inner ramus slightly shorter than outer, of about 12 segments as compared with about 14 in the outer ramus; each segment bears an inner and outer long setose spine at the distal angles.

Uropod 1—The longest, reaching almost as far as uropod 3; rami subequal in length, about three quarters length of peduncle; outer ramus bearing a row of three short spines on inner margin, three or four spines distally, inner ramus of similar structure to outer, distal spines a little stouter than proximal; peduncle with a row of about six short spines on inner margin.

Uropod 2—Reaching to point about three quarters length of uropod 3; inner ramus longer than outer, both of similar structure to those of uropod 1 but with spines on outer margins as well as inner.

Uropod 3—Peduncle short, bearing a stout spine in each distal angle; rami subequal, broad at base and tapering distally, inner ramus overlapping outer dorsally; both rami with strong spines along margins.

Telson—Large, subtriangular with truncated end, deeply cleft, bearing a few slender spines on distal margin.

DESCRIPTION OF FEMALE: Maximum body length recorded 4.1 mm; smaller than males of corresponding age. Apart from the presence of oostegites, females are morphologically similar to males. Oostegites elongate, furnished with long simple spines.

TYPES: *Locality:* The holotype is one of a collection made at Canadian Bay, Port Phillip, Victoria, Australia in March 1963.

Repository: The holotype (No. J.155) and paratypes (No. J.156) are lodged at the Museum of Natural History, Melbourne, Australia.

VARIATION OF MATERIAL EXAMINED: Fourteen specimens were dissected, six of which were female. The male forms varied in length from 4.3 mm to 3.8 mm (S.D. = 0.2); the females varied from 4.1 mm to 3.7 mm (S.D. = 0.2). The first antenna and fifth peraeopod attain the greatest length, the former showing a maximum of 3.0 mm to a minimum of 2.6 mm (S.D. = 0.1), the latter varying from 2.3 mm to 1.9 mm (S.D. = 0.1).

DISTRIBUTION: Present records: *Victoria*—Port Phillip Bay. Canadian Bay (March 1963), Dromana Beach (March 1963), Mornington Beach (March 1963), Rye Beach (March 1963). The recorded distribution of *Amphoedicerus willisi* suggests restriction of the species to the south-eastern coastline of Port Phillip Bay.

ECOLOGICAL NOTES: The species occurs among the seaweeds in small rock pools. It was not observed to be a strong sand burrower.

ANATOMICAL STATISTICS OF *Amphoediceros willisi* (n. sp.)

Characteristic	Maximum (mm)	Minimum (mm)	Mean (mm)	Standard Deviation	Length of appendage/body length ratio
Body length ♀ (Rostrum to telson)	4.1	3.7	3.9	0.2	—
♂	4.3	3.8	4.1	0.2	—
Antenna 1	3.0	2.6	2.8	0.1	0.7
" 2	2.3	1.8	2.1	0.2	0.5
Gnathopod 1	1.3	1.0	1.1	0.1	0.3
" 2	1.3	1.0	1.2	0.1	0.3
Peraeopod 1	1.8	1.4	1.6	0.1	0.4
" 2	1.6	1.4	1.5	0.1	0.4
" 3	1.6	1.4	1.5	0.1	0.4
" 4	1.9	1.5	1.7	0.1	0.4
" 5	2.3	1.9	2.1	0.1	0.5
Uropod 1	1.0	0.8	0.9	0.1	0.2
" 2	0.6	0.4	0.5	0.1	0.1
" 3	0.7	0.4	0.6	0.1	0.1
Pleopod 1	1.3	1.0	1.2	0.1	0.3

Genus *Paroediceropsis* (n.g.)Type species: *Paroediceropsis raymondi* (n. sp.)

DEFINITION OF THE GENUS *Paroediceropsis*: Animal with broadly rounded back; first six peraeon segments contracted, seventh and all pleon segments much broader in lateral view than those anterior to them. Epistome prominent; rostrum weak, eyes large, showing great variability in position, in some specimens lateral, others almost dorsally contiguous.

Antennae well developed. The first peduncular segment of first antenna the longest and broadest of the three. Antenna 1 lacks accessory flagellum. Antenna 2 about one and one half times the length of antenna 1.

Mandible well developed, with strong 3-segmented palp and molar process. Maxillae and maxillipeds normal.

Gnathopods subchelate and well developed.

Peraeopods normal; coxal plates of peraeopods 3, 4 and 5 diminutive. Peraeopod 5 the longest.

Pleopods alike and unmodified.

Uropods normal; uropod 1 the longest.

DIFFERENTIAL DIAGNOSIS: *Paroediceropsis raymondi* (n.g.; n. sp.) shows some resemblance to the genus *Oediceropsis* (Lilljeborg 1865) and the genus *Exoediceropsis* (Schellenberg 1931), but, in this author's opinion, the differences are sufficiently marked to warrant the establishment of a new genus.

The new genus differs from *Oediceropsis* in having well developed third and fourth peraeopods which bear diminutive coxal plates. In addition the first antennae of the new genus are shorter than the second antennae, but by no means as short as in *Oediceropsis* in which they do not reach as far as the second last peduncular segment of the second antennae. In the case of the latter genus, Lilljeborg (1865) claims that the eyes are hardly visible, which is far from the case in the new genus.

The new genus also displays dactyls on the third and fourth peraeopods, the mandibular molar process is powerfully developed, the peduncular segments of the first antennae are not short, and the inner lobes of the first maxillae are spined along the distal margins. In these latter ways the new genus *Paroediceropsis* can be clearly distinguished from the obviously related genus *Exoediceropsis*.

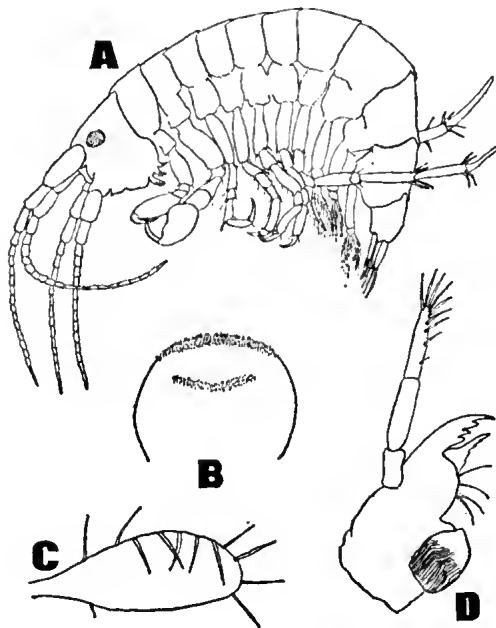


FIG. 12—*Paroediceropsis raymondi* (n. sp.). A. Complete male specimen, c. $\times 37$. B. Upper lip, c. $\times 200$. C. Oostegite (female), c. $\times 75$. D. Mandible, c. $\times 125$.

***Paroediceropsis raymondi* (n. sp.)**

(Fig. 12A-D; 13A-E; 14A-E; 15A-D)

DESCRIPTION OF MALE: Maximum body length recorded 5.0 mm. Head truncated anteriorly. Eyes large, heavily pigmented; position of eyes shows great variability; in some specimens eyes distinctly lateral, in others almost contiguous. Rostrum very small, bluntly rounded. Epistome very prominent. First six peraeon segments contracted; seventh peraeon segment and all pleon segments much broader in lateral view than those of anterior segments of peraeon. Colour, golden brown with characteristic red markings.

Antenna 1—Mean length for the sixteen specimens examined was 1.00 mm (S.D. = 0.4). Flagellum of 15 to 20 segments, the number increasing with age; segments longer than wide, each with a circlet of setae distally. Peduncle, first segment subrectangular; the second a little shorter and considerably narrower than first, tapering distally; the third subrectangular, two thirds length of second. Each peduncular segment with weak spines distally.

Antenna 2—Mean length for the sixteen specimens examined was 1.5 mm (S.D. = 0.5). Flagellum of up to 25 segments, the number increasing with age; segments like those of flagellum of antenna 1. Peduncle, third segment sub-triangular, small; the fourth subrectangular, a little more than twice as long as the first, the fifth subrectangular, as long but narrower than the second. Each peduncular segment with a ring of spines distally.

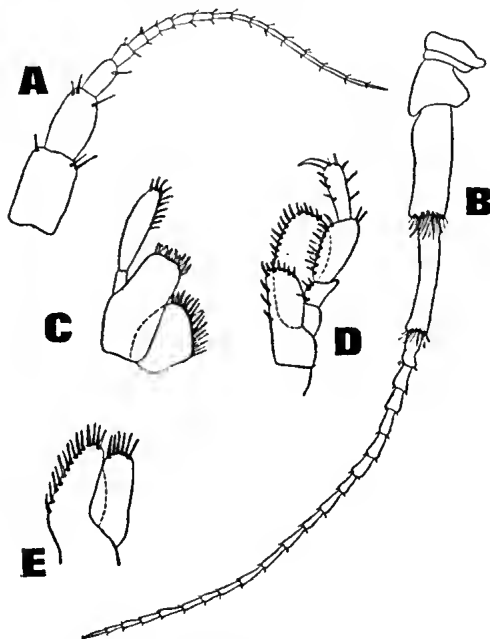


FIG. 13—*Paroediceropsis raymondi* (n. sp.). A. Antenna 1, c. $\times 65$. B. Antenna 2, c. $\times 65$. C. Maxilla 1, c. $\times 22$. D. Maxilliped, c. $\times 15$. E. Maxilla 2, c. $\times 22$.

Mouth Parts—Upper lip rounded, entire, lightly setose distally. Lower lip, outer and inner lobes setose along distal and inner margins. Mandible, cutting edge with four powerful teeth; secondary process well developed; spine row consisting of 4 large spines; molar process large, strongly denticulate; palp three-segmented, first segment short, second segment twice length of first, third tapering, as long as second, lightly spined on inner margin, tipped with several long spines. Maxilla 1, outer lobe subrectangular, bordered distally by a row of nine tooth-like spines; palp slender, two-segmented, broadening distally, tipped with a row of heavy spines; inner lobe as broad as long, provided with long spines along the distal margin. Maxilla 2, lobes equal in length, inner lobe pear-shaped, spined on inner and distal margins, outer lobe subrectangular with row of spines distally. Maxillipeds, inner plate having inner and distal margins straight, outer margin broadly convex, heavily spined on truncated distal border; outer lobes considerably longer and wider than inner, approximating to semi-circular shape, row of spines on inner margin; palp four-segmented, the first segment short, the second three times as long as first, and as long as but broader than the third; the fourth segment short, curved, sharply pointed.

Gnathopod 1—Segment 1 subrectangular, depth about one and one half times width; posterior and distal margins lightly setose. Segment 2 slightly constricted proximally, maximum width about one third length; a few simple spines anteriorly. Segment 3 one and one half times as long as broad. Segment 4, subtrapezoidal, postero-distal margin lightly spined. Segment 5 twice the length of the segment 4, anterior margin broadly convex, posterior margin quite profusely spined. Segment 6 ovate, a cluster of long spines at the antero-distal angle; palm slightly convex, with a small protruberance at the anterior end; numerous small simple spines along the edge. Segment 7 as long as palm, a small spine on outer margin about one third distance from base.

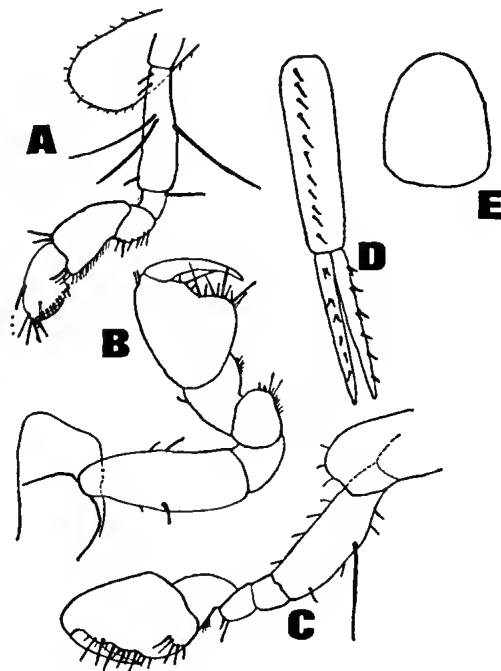


FIG. 14—*Paroediceropsis raymondi* (n. sp.). A. Gnathopod 1 (male), c. $\times 45$. B. Gnathopod 2 (male), c. $\times 50$. C. Gnathopod 2 (female), c. $\times 50$. D. Uropod 1, c. $\times 50$. E. Telson, c. $\times 50$.

Gnathopod 2—Segment 1 similar to that of gnathopod 1, but with postero-distal angle expanding downwards. Segment 2 slightly constricted proximally, length about three times maximum width; a few spines on both anterior and posterior margins. Segment 3 longer than broad. Segment 4 slightly larger than segment 3, a few simple spines postero-distally. Segment 5 slightly larger than segment 4, broadening distally, a few small simple spines posteriorly, one larger spine at the antero-distal angle. Segment 6 large, length about 1.5 times breadth; anterior and posterior margins broadly convex, the whole segment widening distally to palm; palm oblique, slightly excavated in the middle with numerous spines differing in size;

the postero-distal angle bearing clusters of spines. Segment 7 shorter than palm, the tip extending about four-fifths length of palm; segment devoid of spines.

Peraeopod 1—Segment 1 ovate, distal margin rounded; all margins lightly setose. Segment 2 as long as segment 1 is deep, slightly narrower proximally than distally, with several fairly long simple spines, posteriorly and at the postero-distal angle, a few smaller ones anteriorly; length about 3 times maximum width. Segment 3 about as long as wide; a few simple spines postero-distally. Segment 4

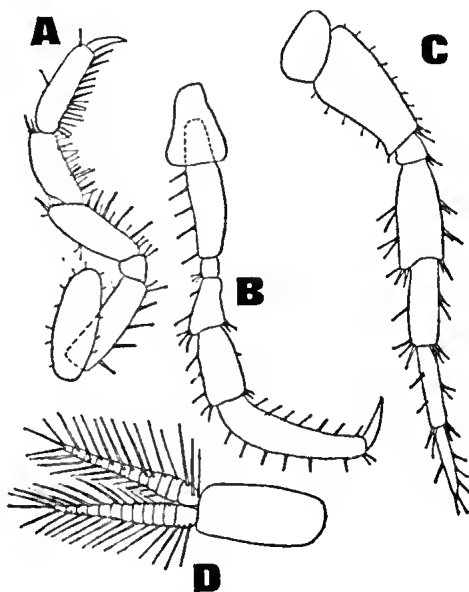


FIG. 15—*Paroediceropsis raymondi* (n. sp.). A. Peraeopod 1, c. $\times 45$. B. Peraeopod 2, c. $\times 50$. C. Peraeopod 5, c. $\times 30$. D. Pleopod 1, c. $\times 35$.

broadening distally, about two thirds the length of segment 2, strongly spined on posterior margin, a few spines along anterior margin. Segment 5 subtrapezoidal, about four-fifths length of segment 4, but narrower; heavily spined on posterior margin; a small cluster of spines at the antero-distal angle. Segment 6 subrectangular, with anterior margin slightly convex; 1.5 times length of segment 5; equipped with profuse long spines along posterior margin; several minute spines along anterior margin. Segment 7 sharp, slightly curved, approximately one third the length of segment 6.

Peraeopod 2—Segment 1 subtrapezoidal, minutely setose. Segment 2 subrectangular, lightly spined on anterior margin, posterior margin setose. Segment 3, subtrapezoidal, slightly longer than wide, a cluster of spines at antero-distal angle. Segment 4 broadening distally; well equipped with stout spines particularly at the antero-distal and postero-distal angles. Segment 5 subrectangular, one and one half times as long as segment 4; similarly spined. Segment 6 subrectangular with curved margins nearly twice length of segment 5; spines on both anterior and posterior margins. Segment 7 sharp, slightly curved; about one half length of segment 6.

Peraeopod 3—A little larger than peraeopod 2. Segment 1, small and produced posteriorly. Otherwise similar to peraeopod 2.

Peraeopod 4—Slightly longer than peraeopod 3, but very similar in structure; segment 1 small and produced posteriorly.

Peraeopod 5—The longest. Segment 1 small, expanded somewhat posteriorly. Segment 2 large, expanded posteriorly, tapering slightly distally; minutely spined along anterior margin, a couple of larger spines at the antero-distal angle. Segment 3 subtrapezoidal, as broad as long, a couple of stout spines at the antero-distal angle. Segment 4 subrectangular, length about two and one half times breadth, postero-distal angle expanded distally; both anterior and posterior margins equipped with clusters of stout spines. Segment 5 as long as segment 4 but narrower; clusters of spines along margins, particularly at the distal angles. Segment 6 as long as segment 5 but narrower; heavily spined at distal angles. Segment 7 about three-quarters length of segment 6 and half as broad; tapering distally and not curved; heavily spined along its length.

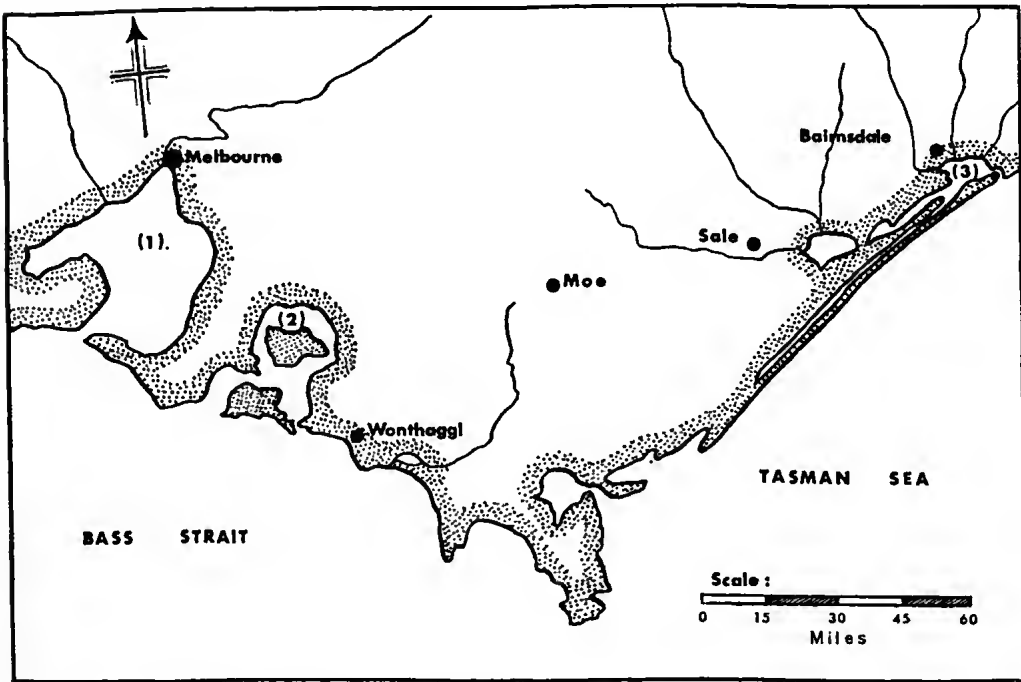


FIG. 16—Eastern Coast of Victoria. Port Phillip Bay (1); Western Port Bay (2); Gippsland Lakes System (3).

Pleopods—All alike and unmodified. Biramous, rami similar and subequal in length with peduncle.

Uropod 1—The largest. Biramous, rami about three-quarters the length of peduncle; a row of short stout spines running along length of peduncle just inside the outer margin.

Uropod 2—Smaller than uropod 1; biramous, inner ramus significantly longer than outer; otherwise similar in structure to uropod 1.

Uropod 3—Smaller than uropod 1; biramous, rami subequal in length with peduncle. Inner ramus slightly longer than outer; both rami supplied with several stout spines on their inner margins. Peduncle subrectangular, bearing several stout spines in the distal region.

Telson—Rounded and entire; devoid of spines.

Gills—Simple sac-like structures.

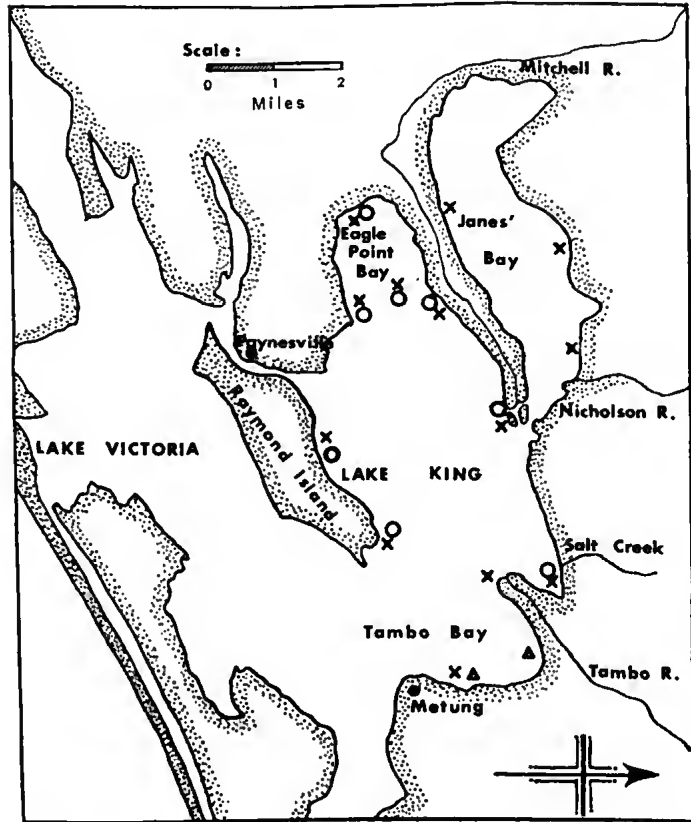


FIG. 17—Lake King showing distribution of new species. *Limnoporeia kingi* (x); *Paroediceropsis raymondi* (o); *Urohaustorius metungi* (Δ).

DESCRIPTION OF FEMALE: Maximum body length recorded 4.5 mm; smaller than males of corresponding age. Apart from gnathopod 2 and oostegite the female is morphologically like the male.

Gnathopod 2—Like that of male except for segment 6 which does not widen distally to palm as does male. In the female segment 6 is more broadly ovate than is the male.

Oostegites—Subovate; equipped with spines of varying length around the margin.

Types: *Locality*—The holotype is one of a collection made at Eagle Point Bay, Lake King, Victoria, Australia in June 1956.

Repository—The holotype (No. J.157) and paratypes (No. J.158) are lodged at the Museum of Natural History, Melbourne, Australia.

VARIATION IN MATERIAL EXAMINED: Sixteen specimens were dissected and measured; the males, of which eleven were dissected, varied in length from 5.0 mm to 1.75 mm with a mean length of 2.9 (S.D. = 0.8), while the females varied in length from 4.5 mm to 1.5 mm with a mean length of 2.5 mm (S.D. = 0.7).

The second antennae show a considerable degree of variability, with specimens ranging from 2.5 mm to 0.5 mm with a mean length of 1.5 mm (S.D. = 0.5). The fifth pereopod, the longest, ranges in length from 3.0 mm to 1.5 mm with a mean length of 2.2 (S.D. = 0.4).

DISTRIBUTION: Present records: *Victoria*, Lake King (April 1957). This species appears to be widely distributed in the main body of Lake King in association with *Limnoporeia kingi*. The specific name is derived from the name of Raymond Island along the shores of which this animal is common.

ECOLOGICAL NOTES: The species was observed to burrow in both coarse and fine sand as well as mud. This is not surprising as the form is structurally well adapted for burrowing.

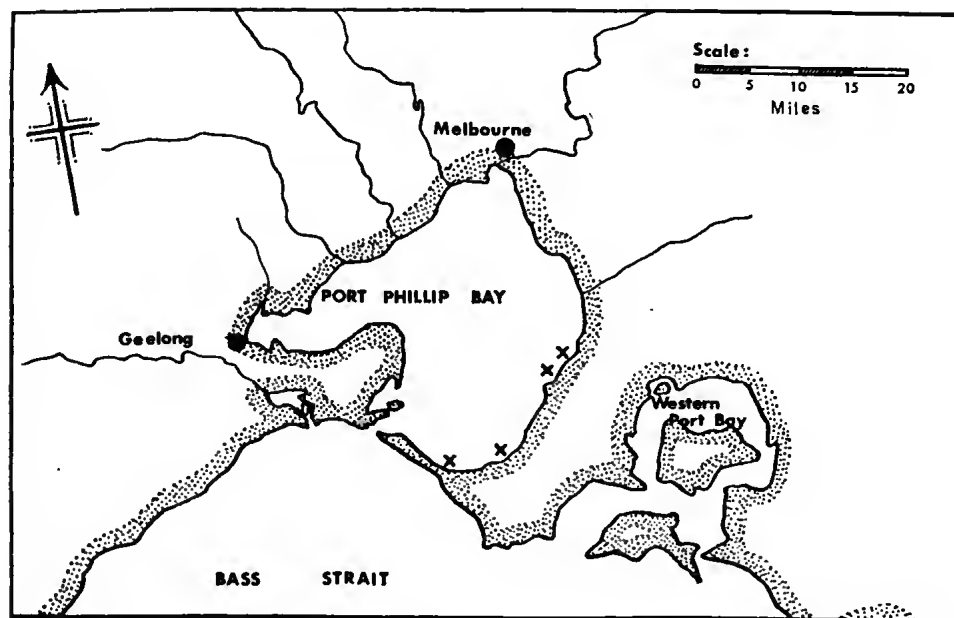


FIG. 18—Port Phillip and Western Port Bays showing distribution of *Amphoediceros willisi* (x).

ANATOMICAL STATISTICS OF *Paroediceropsis raymondi* (n. sp.)

Characteristic	Maximum (mm)	Minimum (mm)	Mean (mm)	Standard Deviation	Length of appendage/body length ratio
Body length ♂ (Rostrum to telson)	5.0	1.75	2.9	0.8	—
♀	4.5	1.5	2.5	0.7	—
Antenna 1	1.5	0.25	1.0	0.4	0.3
" 2	2.5	0.5	1.5	0.5	0.5
Gnathopod 1	1.25	0.5	1.0	0.2	0.3
" 2	1.75	0.75	1.3	0.3	0.5
♂	1.25	0.75	1.0	0.2	0.3
♀	2.0	0.75	1.2	0.3	0.4
Peraeopod 1	2.0	0.75	1.2	0.3	0.4
" 2	2.0	0.75	1.2	0.3	0.4
" 3	2.25	0.75	1.5	0.3	0.5
" 4	2.5	1.0	1.6	0.1	0.6
" 5	3.0	1.5	2.2	0.4	0.8
Uropod 1	1.5	0.5	0.9	0.3	0.3
" 2	1.25	0.5	0.8	0.2	0.3
" 3	1.0	0.25	0.6	0.3	0.2
Pleopod 1	1.5	0.5	1.0	0.3	0.3

Acknowledgements

In carrying out this and related studies the author had valued assistance from many sources. However, grateful acknowledgement is due chiefly to Mr. A. G. Willis of the University of Melbourne for his constructive criticism and encouragement over a considerable number of years.

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AN INTRODUCTION TO THE REGENERATION OF MALLEE EUCALYPTS

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Abstract

Exploratory studies were conducted on some aspects of the germination and seedling establishment of *Eucalyptus diversifolia*, *E. incrassata* and *E. oleosa*. Germination was found to be controlled principally by soil moisture and temperature, and soil chemical factors were unimportant. Field germination in 1966 was shown to occur in the autumn-winter period. Seedling establishment appeared to be limited primarily by reduced soil moisture in the spring-summer period. Frost significantly reduced seedling numbers in winter, especially on low-lying sites. Some possible processes by which stands of mallee eucalypts regenerate are discussed.

Introduction

Although mallee eucalypts are frequently observed to recover from burning or felling by the growth of new shoots from the established lignotuber, nothing is known of the factors controlling this process. Mallee eucalypt regeneration from seed is observed occasionally, and this process is also poorly understood. In some areas, seed regeneration is almost invariably destroyed by introduced herbivores, especially rabbits (Zimmer 1940a). The only account of regeneration from seed is that of Zimmer (1940b). On this occasion, seedlings were recorded in December following a fire which destroyed all aerial plant parts the previous January. Regeneration from lignotubers proceeded concurrently with seedling establishment (Zimmer 1940b). The seedling regeneration was of *E. incrassata* Labill. and *E. foecunda* Schau. and rabbits were scarce in the area (W. J. Zimmer, Eastern Hill, Creswick, Victoria; pers. comm.).

This paper reports some short-term exploratory studies on the germination and seedling establishment of the following mallee eucalypts.

(1) *E. diversifolia* Bonpl. This species has a wide edaphic range, and has been found on acidic to neutral deep siliceous sands extremely deficient in all plant nutrients, on highly alkaline deep calcareous beach sands adequately supplied with macronutrients, as well as on a range of nutritionally intermediate soils (Parsons & Specht 1967).

(2) *E. incrassata* Labill. This species is also found on soils with a wide range of pH, calcium carbonate and available nutrient content (Parsons & Specht 1967).

(3) *E. oleosa* F. v. M. ex Miq. This name will be used here to refer to the form of the *E. oleosa* species complex with dull or subglaucous leaves and rostrate operculi, following the work of Mr I. Brooker, Australian National University (pers. comm.). It was previously known as *E. oleosa* var. *glauca* Maiden and *E. transcontinentalis* Maiden. This taxon is found only on alkaline soils containing free calcium carbonate.

All three species are widespread throughout mallee areas in southern Australia (Litchfield 1956).

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Methods and Results

LABORATORY GERMINATION: An experiment was set up

- (1) to determine the effect of a range of chemically contrasting mallee topsoils on % germination of the three species, and
- (2) to compare the % germination of two populations of *E. diversifolia* from chemically contrasting soils to see if intraspecific differentiation in germination response to soil chemical factors had occurred in this species.

E. oleosa and *E. incrassata* seeds were collected from the field trial site described later. The *E. incrassata* population sampled conformed to the description of *E. incrassata* var. *costata*, which, however, is probably insufficiently distinct to warrant varietal status.

Seeds of *E. diversifolia* from deep siliceous sand (*E. diversifolia* W) and from deep calcareous beach sand (*E. diversifolia* R) were collected from sites at Waitpinga and Robe, South Australia, respectively (see Parsons & Specht 1967).

The soil samples used (Table 1) covered the entire pH and calcium carbonate range of mallee topsoils—from highly alkaline calcareous sand to slightly acidic siliceous sand very low in calcium.

TABLE 1
Soil Sources for the Laboratory Germination Experiment
Soil Sample (0-1")

Sample description	D	M	I
	Calcareous sand	Loamy sand	Siliceous sand
Sample pH	8.3	7.9	6.6
Profile description	Deep calcareous beach sand	Shallow soil on limestone	Duplex sandplain soil
Locality	Robe, S. Aust.	1 mile W. of Tintinara, S. Aust.	Field trial site
Eucalypts present	<i>E. diversifolia</i>	<i>E. diversifolia</i> <i>E. incrassata</i> <i>E. oleosa</i>	<i>E. incrassata</i>

Equal weights of air-dry soil were added to petri dishes to provide two replicates of each species-soil combination. The soil was maintained in excess of field capacity by watering to 25% moisture content every two days. A control was provided using 'Whatman' seed test circles in petri dishes to provide two replicates per species.

Weighed seed samples were spread evenly over the watered soils in petri dishes on 17 January 1966. The dishes were supplied with light and a constant temperature of 77°F, which are optimal for germination of these species (Grose 1962). Germinations were counted when necessary until the end of the experiment on 24 March 1966, a period of 66 days. Germinates were removed from the dishes when counted.

Although some slight differences in germination rate were found between the various substrates used, these may be caused by small differences in substrate moisture characteristics (Collis-George & Sands 1959), so that rate comparisons

between substrates are not relevant here. The number of seeds germinating per weighed sample during 66 days on the seed test circles at 77° F (after which germination has ceased) will be called the laboratory germination capacity. Total germination is expressed as a % of the laboratory germination capacity. At 66 days, occasional germinations of *E. oleosa* and *E. diversifolia* were still occurring on the three soils.

No marked effects of soil type on % germination were found (Table 2). *E. incrassata* seeds had the fastest germination rate on all substrates, and *E. oleosa*

TABLE 2
The Laboratory Germination of Four Populations on Seed Test Circles and Three Soils

Population		Total germination on seed test circles*	% germination on soil		
			D	M	I
<i>E. diversifolia</i>	R	242	100	100	99
<i>E. diversifolia</i>	W	108	94	77	100
<i>E. incrassata</i>		650	85	82	86
<i>E. oleosa</i>		596	76	78	81

* Sums of two replicates

the slowest (Fig. 1). There was a marked difference in the fertility of the two *E. diversifolia* seed collections (Table 2), and such intraspecific variability appears to be common in eucalypts (Larsen 1965).

With *E. incrassata* and *E. oleosa*, total germination lower on soils than on seed test circles (Table 2) may be due to seed attack by soil micro-organisms or the presence of some other germination inhibitor in all three soils.

THE FIELD TRIAL: This trial was conducted to investigate germination and seedling establishment of *E. incrassata* and *E. oleosa* under field conditions. In addition, it was hoped that the trial would provide information on the relative performance of these two species on two contrasting soils, one of which was a soil type from which *E. oleosa* is entirely absent in the field.

The trial was conducted in the Ninety Mile Plain, South Australia, where detailed information on soils and vegetation was already available.

An area was chosen in a strip of mallee surveyed as a road between Sections 10 and 11, Hundred of Cannawigara, which was mature and relatively undisturbed except for an access track. The soils and climate of this area have been described by Blackburn *et al.* (1953) and the vegetation by Litchfield (1956). The area chosen provided two distinct soil associations carrying different combinations of eucalypts in a small area. Plots were set up on both soil associations.

(1) *The Willyama association.* The well drained parts of the Willyama association in this area carry a stand of mallee dominated by *E. incrassata* and *E. oleosa*, with some *E. foecunda* and an understory dominated by *Melaleuca uncinata*.

The soil profile is as follows:

- 0-4 in. Light brown sand.
- 4-20 in. Yellowish brown sandy clay with few lime nodules.
- 20-62 in. Yellowish brown sandy clay, with much lime in hard and soft states. In places the profile is entirely hard and soft lime from 20 in. onwards.

This profile is typical of the shallow duplex soils on limestone plains in the Ninety Mile Plain, and they usually carry this assemblage of eucalypts. The site on this soil (which is referred to as the *E. oleosa* site) was the seed source for both species.

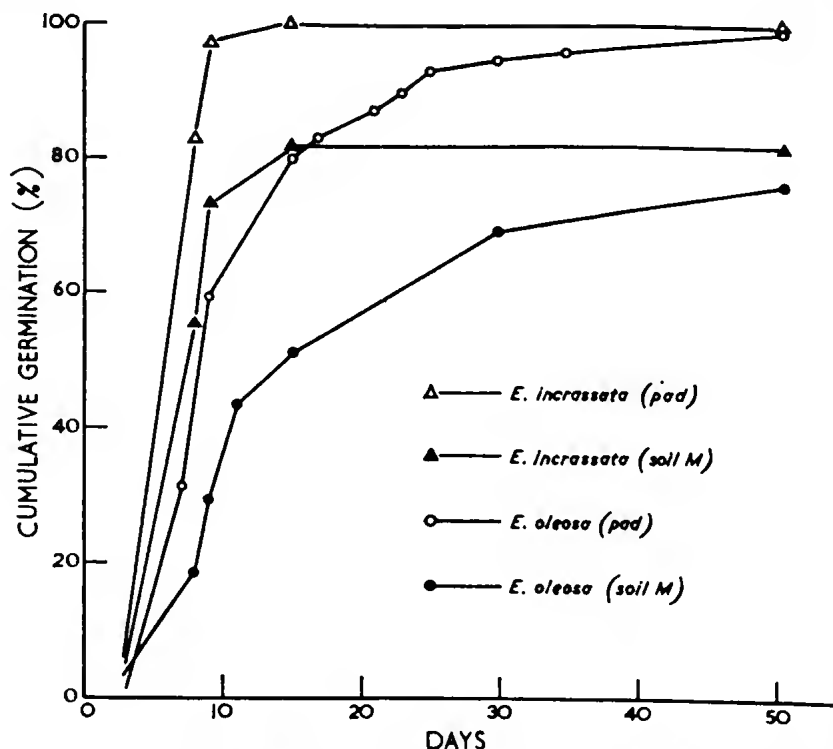


FIG. 1—Germination rates of two species on seed test circles ('pad') and soil M.

(2) *The Buckingham association.* These soils occurred one mile E. of, and at a slightly higher altitude than, the Willyama association. In this area they carry *E. incrassata* with less *E. foecunda* over *Melaleuca uncinata*. The plots were set up on a soil with the following profile:

- 0–12 in. Greyish-brown sand.
- 12–18 in. Tough columnar mottled yellowish brown, brown and grey sandy clay.
- 18–33 in. Mottled yellowish brown and brownish yellow sandy clay.
- 33–38 in. As above with a few flecks of soft lime.

This is a duplex sandplain soil with tough clay subsoil typical of the duplex soils carrying *E. incrassata* throughout the Ninety Mile Plain. *E. oleosa* is invariably absent from such soils. This site is referred to as the *E. incrassata* site.

At each site, two 59 sq. ft plots were selected in relatively open parts of the community (so that large lignotubers were absent), were cleared of aerial plant parts and litter, and fenced against rabbits. Large shoots were removed for 6 ft around each plot to minimize variation in shading effects between plots. Within each fenced plot were two seed beds, each 15 sq. ft in area, two seedling beds,

each 3 sq. ft in area, and an access path through the middle of the plot, containing a rain gauge.

Seeds and seedlings were planted at four intervals between 24 April 1965 and 13 September 1965 in one randomly chosen seed bed and seedling bed. Observations continued until 1966. At each planting, one seed bed at each site was sown with a seed mixture containing 2.0 g of *E. incrassata* seed and 1.0 g of *E. oleosa* seed (chaff removed by sieving in both cases).

A seed mixture was used so that the environments for seedlings of each species would be as similar as possible, and to include the possibility of interaction between seedlings of the two species in the experimental design.

The seed was covered with a thin ($\frac{1}{4}$ - $\frac{1}{2}$ in.) layer of topsoil after broadcasting, to minimize harvesting by ants. Germination tests in a 77°F constant-temperature room both before the first planting and after the last planting showed no appreciable change in the fertility of the seed lots with time, and established that the 1.0 g-2.0 g mixture contained 1120 fertile seeds of *E. oleosa* and 1150 fertile seeds of *E. incrassata*.

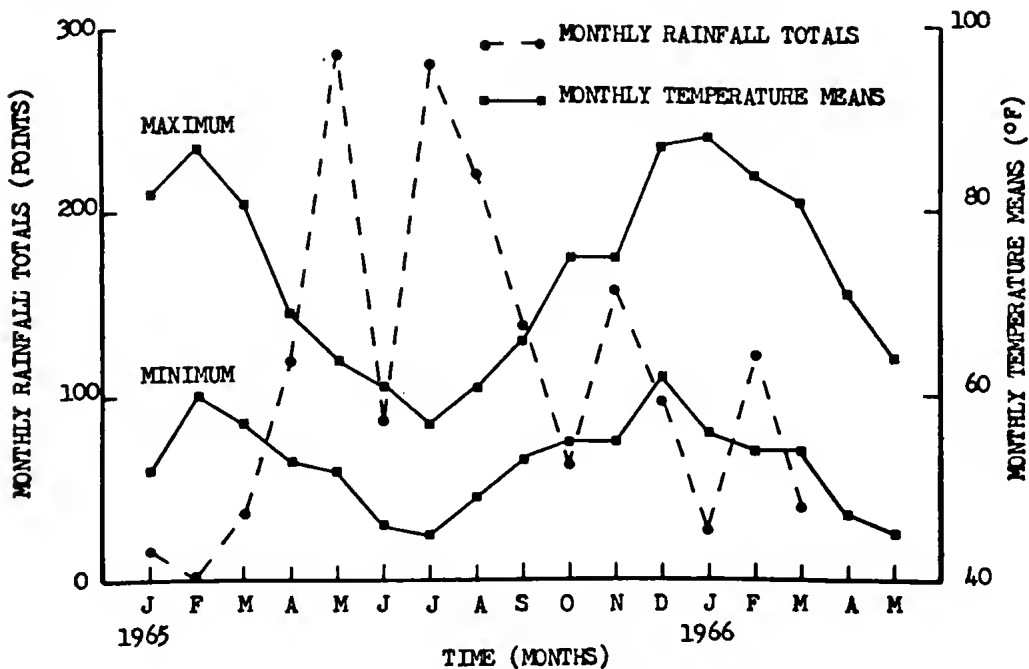


FIG. 2—Monthly meteorological data recorded during the field trial by stations nearby.

Seedlings were transplanted in the field ten days after germination (when their root systems were 2-3 in. long), and were washed free of soil before transplanting. Ten seedlings were transplanted at each site at every planting.

Rainfall data only were recorded at the experimental sites—temperature data are taken from the Keith Meteorological Station, approximately 15 miles E., and monthly rainfall data from Wirrega (Fig. 2), 5 miles SW.

The seedling beds were used as controls to check on germination of the two eucalypts from natural seed fall. No such germination was recorded at any time.

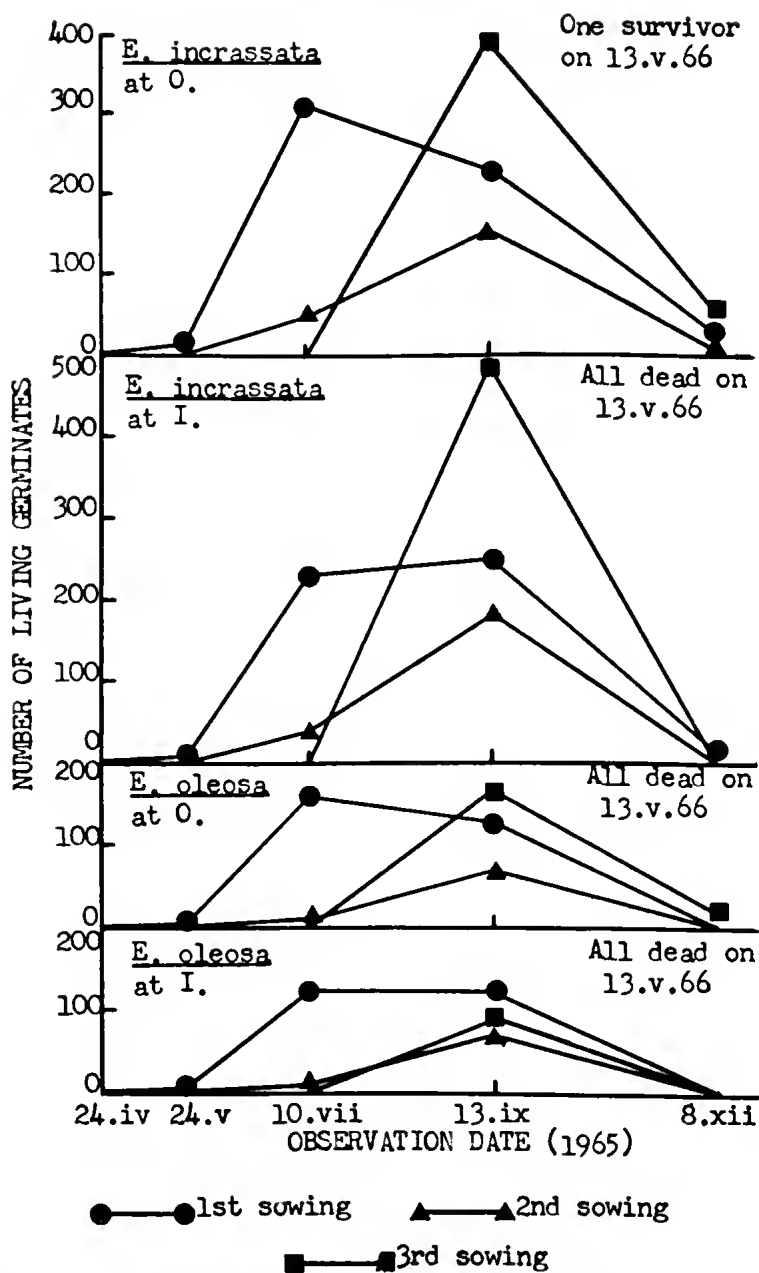


FIG. 3—The number of living germinates present in the plots from three successive sowings of mixed seed of two species on two soils. O = *E. oleosa* site, I = *E. incrassata* site. All seeds sown on 13/ix/65 failed to germinate.

The trial was commenced on 24 April 1965, and concluded on 13 May 1966, when road-building operations to a newly developed quarry destroyed half the plots.

(a) *Results of the seed sowing experiment.*

The results of this experiment are summarized in Fig. 3. Field germination is expressed as a % of laboratory germination capacity. As field germination was determined from the emergence of the cotyledons from the soil, no data on pre-emergence deaths were obtained and all germination figures represent net germination only.

The rainfall observations showed that rainfall was closely comparable at the two sites.

TABLE 3

Winter Deaths of Germinates as a % of the Total Number of Germinates; and Number of Delayed Germinations recorded in the Second Autumn of the Experiment
I = *E. incrassata*; O = *E. oleosa*

Sowing date	Site	Winter deaths (%) of each species (all recorded on 13.ix.65)		Delayed germinations of each species (all recorded on 13.v.66)	
		O	I	O	I
24.iv.65	O	11	17	7	—
	I	—	2	—	—
24.v.65	O	16	27	4	—
	I	6	5	—	—
10.vii.65	O	—	—	2	—
	I	—	—	—	—
13.ix.65	O	—	—	1	—
	I	—	—	—	—

(1) *Germination*: Germination for both species occurred throughout the period May to at least July, the period of greatest soil moisture. All total germinations for the late May sowing were lower than the totals from both the late April sowing and the July sowing (Fig. 3). This reduction of germination was much more marked on the low-lying *E. oleosa* site. The two months following the May sowing were colder than the two months following the other two sowings (Fig. 2), so that the available data suggest a depressing effect of low temperature on germination or pre-emergence seedling survival. The September sowing completely failed to germinate, almost certainly as a result of low rainfall and therefore dry soil conditions in this period (Fig. 2). However, germination may occur in spring in wetter years than 1965, which had a spring rainfall considerably below average (spring rainfall 1965 = 356 points, mean spring rainfall = 578 points).

Maximum germination in the plots varied from 7% to 44% of the laboratory germination capacity. In similar studies, but without a protective soil covering on the seeds, Florence (1961) recorded a range from 3% to 34% for *E. pilularis* Sm. and Cunningham (1960) a range from 8% to 12% for *E. regnans* F.v.M.

Percentage germination of *E. incrassata* was much greater than that for *E. oleosa* at both sites for all plantings (mean % germination of *E. incrassata* for all sowings = 27%; of *E. oleosa* = 10%).

The germination of each species was similar on the two soils studied, in agreement with the laboratory study.

When the plots were inspected in May 1966, following autumn rains, some new germination was observed at the *E. oleosa* site on the plots sown in April, May and July 1965 (Table 3). This delayed germination was all of *E. oleosa*.

(2) *Establishment and survival of germinates*: In general, seedling numbers reached a maximum two to four months from sowing, and then showed a very marked decline with the onset of drier soil conditions and higher temperatures in late spring and early summer (Fig. 3). In addition, the September plot inspection revealed a number of dead seedlings (Table 3) at a time when rainfall records and soil inspection at both sites showed that soil moisture was optimal. The period between the July inspection, when no deaths were apparent, and the September inspection coincided with the period of most severe frosts in the area, when three daily minimum screen temperatures below 29.5°F were recorded at Keith. This suggests that the deaths were caused by frost, and this hypothesis is supported by the following observations: (a) Death percentages were much higher at the low-lying *E. oleosa* site, where lower temperatures caused by cold air drainage would be expected. Comparative daily ground-level temperature observations at the two sites in May 1966 showed that the *E. oleosa* site was 4-6°F colder than the *E. incrassata* site. (b) No symptoms of 'damping-off' or other fungal infections were observed on either dead or damaged seedlings.

The winter deaths observed were all of seedlings from the April and May sowing. It appears that the seeds sown later were prevented from germinating by the cold July-early August weather, and germinated in the warmer weather of late August, thereby escaping frost damage.

By December, almost all the seedlings were found to be dead. These losses coincided with dry soil conditions caused by low rainfall and high temperatures (Fig. 2). The losses then, are most likely to be due to drought and possibly also to lethal temperatures on the hypocotyl at the soil-air junction (Cunningham 1960). By May 1966 only one seedling remained alive. This seedling, of *E. incrassata*, was 2.5 cm high and at the four-leaf stage.

(b) *The results of the seedling transplant experiment.*

The seedlings transplanted in late April had all died by May, reflecting the low levels of soil moisture in the first part of this period. Otherwise the pattern of survival was similar to that of the seedlings from the sowing experiment, with some winter losses suggesting death by frost, and the death of the remaining seedlings during the summer drought.

Discussion

The laboratory germination experiment showed that soil chemical properties do not appear to exert significant effects on the germination of the four populations examined; if such properties influence the distribution of the three species, they must do so at later stages of the life cycle.

This finding contrasts with the marked inter- and intra-specific differentiation in germination response to these factors shown elsewhere (Mayer & Poljakoff-Mayber 1963, Ramakrishnan 1965).

E. incrassata seeds are completely non-dormant (Larsen 1965), and this behaviour explains the absence of delayed germination in the field (Table 3). By contrast, *E. oleosa* seeds are rated as 'dormant' by Larsen (1965) and they show delayed germination in the field. The slower germination rate (Fig. 1) and lower

field germination capacity (Fig. 3) recorded for *E. oleosa* are probably related to this dormant behaviour.

The ecological significance of these differences in dormancy needs to be assessed in a long-term study of regeneration from seed covering a range of climatic regimes, and in conjunction with studies on the relative seed production of the two species. It is possible that the dormancy of *E. oleosa* seeds is one of the factors enabling *E. oleosa* to establish in drier areas than *E. incrassata*.

The observations of Zimmer (1940b) established that natural regeneration of mallee eucalypts from seed can occur following the marked reduction of community transpiration caused by bush fires. However, it is probable that competition for water from the faster-growing lignotuber regeneration would be lethal for at least some of the seedlings.

In the present study, although aerial plant parts were removed from the plots themselves, many roots from actively transpiring plants nearby were certainly present. Under these conditions, and in the climate prevailing during the study, survival of seedlings through the summer was negligible, the principal limiting factor being the dry spring and summer climate. However, these results apply only to years of sub-average spring rainfall like 1965, and seedling establishment may have been significant if rainfall had been average or above average. Elsey (1957) reached similar conclusions in his study of *Callitris* regeneration in the Warby Ranges, where spring and summer rainfall is again the principal determinant of seedling survival in the first year. He recorded a year of sub-average August-October rainfall which killed all *Callitris* germinates of that year, occurring between two years of above average August-October rainfall in which plentiful seedling establishment occurred. Elsey (1957) also found that seedlings that survived the first summer were seldom killed by drought in the second or later years.

Seedling establishment in gaps in a mature stand, such as in the plots of the present study, may exist as small lignotubercous advance growth (Jacobs 1955) until death of the mature trees makes water available for more rapid growth. Such an establishment pattern has been demonstrated in *E. marginata* stands by van Noort (1960), where such lignotubercous advance growth may exist in a 'dormant' phase beneath mature forest for more than 20 years.

In the case of destruction of the aerial parts of mature mallee stands by fire, regeneration from lignotubers has a marked advantage over seedling regeneration. In the present study, some mature mallee stems were cut down while erecting the plots. The remaining lignotubers produced new shoots in spring 1965. In May 1966 these shoots were up to 32 cm long and each shoot carried up to 11 large leaves, while the surviving seedling was only 2.5 cm high with 4 very small leaves. This suggests that the regrowth from the lignotubers will kill or suppress seedling regeneration which may only establish in gaps formed when degenerate lignotubers rot and die. If degenerate lignotubers are simultaneously killed by fire, then an even-aged crop of seedlings may become established.

Another aspect requiring investigation is the age at which mallee eucalypts first produce seeds. On 23 November 1959 fire destroyed all aerial parts of a stand of *E. incrassata* and *E. foecunda* in Wyperfeld National Park. When examined on 15 July 1967 lignotuber regeneration of both species was carrying what appeared to be the first crop of fruits since the fire (R. Campbell, Yaapect, pers. comm.). No data are available on time from germination to production of first fruit crop.

Clearly, long-term studies with more replication than was possible in the present work are needed to investigate thoroughly the biology of mallee eucalypts and many other native plant species.

Acknowledgements

It is a pleasure to thank Professor J. S. Turner and Professor R. L. Specht for advice and criticism, and the Australian Meat Research Committee for financial support.

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TAXONOMY OF SOME CRETACEOUS SPORES AND POLLEN GRAINS FROM EASTERN AUSTRALIA

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Abstract

Twenty-five species of plant microfossils from various Cretaceous sections in eastern Australia are systematically examined and illustrated. Of these, one Neocomian spore type is instituted as a new species; eight new species of spores and pollen grains from the late Albian-Upper Cretaceous are proposed; and the remaining forms, all from post-Aptian sediments, are assignable to existing Australian and overseas species of Cretaceous and Tertiary age. Particular attention is given to the nature, distribution, and stratigraphic significance of Australian schizaeaceous trilete spores (allocated to *Cicatricosisporites* and *Appendicisporites*); and to the oldest pollen representatives of the angiosperms. Pollen of the *Nothofagus brassi* type is recorded and described for the first time from the Australian Cretaceous, where it appears (as *Nothofagidites senectus* sp. nov.) initially in Senonian strata.

Introduction

During the course of a palynological review of the Australian Cretaceous System (Dettmann & Playford 1968), it became obvious that, while palynological contents of the Lower Cretaceous are well known, few published data existed on spore-pollen composition of Upper Cretaceous deposits. Accordingly, the purpose of the present paper is to describe, formally designate, and illustrate certain species of spores and pollen, the majority of which have stratigraphic and/or palaeobotanical significance in the mid-late Cretaceous of the eastern Australian region. Although these comprise only a minor proportion of the number of spore-pollen types present in the Upper Cretaceous, they are selected here to illustrate qualitative changes in the microfloral sequence, and to provide a systematic basis for the palyno-stratigraphic zonation (proposed by Dettmann & Playford 1968) of this lesser known part of the Cretaceous section. Clearly therefore this paper is to be regarded as a taxonomic complement to the Dettmann & Playford review paper (in press).

Forms described herein have been recovered from various subsurface sections in Victoria, South Australia, and Queensland. The precise localities of all type and other illustrated species are listed in the systematic section under each species and in the plate explanations. General indication of the known lateral and vertical distribution of each form is also given in the text, in which reference is made to the biostratigraphic units defined on spore-pollen criteria by Dettmann & Playford (1968). In ascending order these units, which span the Cretaceous System of eastern Australia, are: *Crybelosporites stylosus* Zone (?uppermost Jurassic-Valanginian); *Dictyotosporites speciosus* Zone (Valanginian-Upper Aptian), comprising *Cyclosporites hughesi* Subzone and *Crybelosporites striatus* Subzone; *Coptospora paradoxa* Zone (Upper Aptian-Upper Albian); *Tricolpites pannosus* Zone (Upper Albian-?Cenomanian); *Appendicisporites distocarinatus* Zone (?Cenomanian-?Turonian); *Clavifera triplex* Zone (?Turonian-?Coniacian); *Tricolpites*

pachyexinus Zone (Santonian); and an informal unit containing the *Nothofagidites* Microflora (Santonian-uppermost Cretaceous).

The rock samples upon which this study is based were prepared according to the laboratory techniques described by Dettmann (1963).

Plant microfossil specimens that are illustrated herein have been lodged in one of the following institutions: National Museum of Victoria, Melbourne (specimen number prefixed 'P'); Mines Department of Victoria, Melbourne ('GSV'); Department of Geology & Mineralogy, University of Queensland, Brisbane ('Y'). Vernier readings quoted are those of Leitz Ortholux microscope no. Mx2188 in the University of Queensland. A master slide labelled with reference to this instrument accompanies the collections.

Systematic Palynology

Forms referable to the *Anteturma Sporites* are here categorized according to the scheme of Dettmann (1963); pollen conforming with the *Anteturma Pollenites* are classified within Potonié's (1958, 1960) suprageneric groups. Dimensional and nomenclatural terminology adopted by Dettmann (1963) is followed throughout; terms applicable to angiospermous pollen are those of Erdtman (1952). Unless stated otherwise, sizes quoted are based upon twenty suitably orientated specimens.

ANTETURMA **SPORITES** H. Potonié 1893

TURMA TRILETES Reinsch emend. Dettmann 1963

Suprasubturma ACAVATITRILETES Dettmann 1963

Subturma AZONOTRILETES Lubert emend. Dettmann 1963

Infraturma LAEVIGATI Bennie & Kidston emend. Potonié 1956

Genus **Stereisporites** Pflug 1953

TYPE SPECIES (by original designation in Thomson & Pflug 1953: *Stereisporites stereoides* (Potonié & Venitz) Pflug 1953.

DISCUSSION: The Australian Upper Cretaceous spores of *Stereisporites viriosus* sp. nov. possess a distal circumpolar ridge and do not strictly conform with the genus as defined by Potonié (1956) and as used by many subsequent authors (e.g. Manum 1962). *S. viriosus* shows some similarity to *Staplinisporites* Pocock 1962 but lacks a distal polar thickening and radially arranged distal sculptural elevations. The faint distal radial striations exhibited by the species are considered to be a property of exine structure rather than of sculpture.

Krutzsch (1963b) allocates to *Stereisporites* a diversity of morphological types; clearly, those with well-developed sculpture and/or equatorial thickening are more appropriately placed within genera of the Apiculati and the Cingulati.

Stereisporites viriosus sp. nov.

(Pl. 6, fig. 1, 2)

DIAGNOSIS: Microspores radial, trilete, biconvex, the proximal surface pyramidal. Amb convexly subtriangular to subcircular. Laesurae straight, extending to equator with lips that are elevated extensions of exine. Lips 3-5 μ high at pole, where they are sometimes flattened against laesurate margins; tapering in height towards equator. Exine 3-4 μ thick. Proximal surface smooth to faintly scabrate. Distal surface with very fine, faint, radial striations and low, 2-3 μ wide, circumpolar ridge that is concentric with, and two-thirds to five-sixths radius of, amb;

exine adjoining inner margin of ridge has coalescent grana and low verrucae $2-3\mu$ in basal diameter.

DIMENSIONS: Equatorial diameter (15 specimens) 63 (74) 85μ .

HOLOTYPE: Preparation F368/4, 30.3 115.7, GSV 61863. Pl. 6, fig. 1, 2. Distal aspect. Amb convexly subtriangular, diameter 83μ ; laesurae 42μ long; lips 5μ high at pole but flattened against laesurae at margins; exine 4μ thick; distal circumpolar ridge 2μ wide, encloses circular area 65μ in diameter; coalescent grana and verrucae adjacent to ridge's inner margin; faint fine striations radially arranged in distal exine.

TYPE LOCALITY: Victoria, F.B.H. Port Campbell No. 4 well, 3821-38 ft (core 7).

COMPARISON: This species is distinct from other Australian members of the genus in its larger size, radial striation, thick exine, and in the form of the distal circumpolar ridge. It resembles *Psilatrites radiatus* Brenner 1963, the illustrated holotype (Pl. 20, fig. 7) of which appears to possess a distal circumpolar ridge. However, Brenner's species is smaller, has a thinner exine, and lacks well-developed laesurate lips. *Stereisporites maximus* Krutzsch 1963 resembles *S. viriosus* sp. nov. but lacks a distal circumpolar ridge. Other acingulate species assigned by Krutzsch (1963b) to the genus are considerably smaller than *S. viriosus* and differ in distal characteristics.

DISTRIBUTION: This form occurs infrequently, but appears to be of stratigraphic significance in the Upper Cretaceous of the Otway Basin. Its first appearance is within the *Tricolpites pachyexinus* Zone and it extends into the *Nothofagidites* Microflora.

Infraturma MURORNATI Potonié & Kremp 1954

Genus *Cicatricosisporites* Potonié & Gellertich 1933

TYPE SPECIES (by original designation): *Cicatricosisporites dorogensis* Potonié & Gellertich 1933.

DISCUSSION: Spores attributable to *Cicatricosisporites* Potonié & Gellertich 1933 are characterized by distal, equatorial, and sometimes proximal cicatricose sculpture. The majority of species included within the genus have been described from northern hemisphere Cretaceous and Tertiary sediments which often contain an almost overwhelming diversity of cicatricose elements. Many of the species apparently received only superficial examination, and were inadequately described and poorly typified. Because of this, some subsequent authors have incorrectly assigned diverse morphological types to the original specific categories; or have instituted a new taxon where an existing one was applicable. These practices have not only obscured the stratigraphic value of particular forms but have also contributed to the present state of taxonomic disorder that exists in relation to *Cicatricosisporites*. An obvious and relevant example is the allocation of innumerable Cretaceous and Tertiary forms to *C. dorogensis* Potonié & Gellertich 1933, which was originally described from the Eocene of Europe. It is now realized by some authors that few, if any, of the Cretaceous forms remotely resemble *C. dorogensis* (see Hughes & Moody-Stuart 1966, p. 287).

In Australia, the genus is almost invariably present in Lower and mid Cretaceous sediments, and is represented by only about ten distinct morphological types. The first record of Australian *Cicatricosisporites* is that of Cookson (1953b) who instituted the most commonly occurring species, *C. australiensis* (Cookson)

Potonié 1956. Later, Dettmann (1963) described three further species from the Australian Lower Cretaceous, all readily distinguishable from one another and from *C. australiensis*, and thus not forming links in a cicatricose morphological series. A fifth Australian species is described in this paper.

The criteria considered by Dettmann (1963, p. 52) to be of taxonomic significance are: "shape of muri, both in optical section and surface view; width of four adjacent muri and lumina in distal, interradian regions; relative width of muri and lumina; arrangement of muri; length of laesurae; and shape of amb". Some or all of these criteria have been used by Delcourt & Sprumont (1955), Kedves (1960, 1961), and Deák (1963, 1965), in the delineation of northern hemisphere species. Hughes & Moody-Stuart's (1966) study of *in situ* schizaceaceous spores conforming with *Cicatricosisporites* shows convincingly that the shape, spacing, and orientation of the muri together with laesurate features are valid taxonomic grounds for specific discrimination.

Documentation of these features at specific level involves detailed descriptions and adequate illustrations at critical orientations. Clear photographs of well-preserved specimens are of course essential; and supplementary idealized diagrams of the kind introduced by Deák (1963, Pl. 1, fig. 1-3) are most helpful in gaining a three-dimensional appreciation of the sculptural detail. Deák's diagrammatic procedure is applied here (Fig. 1) to the five named Australian species

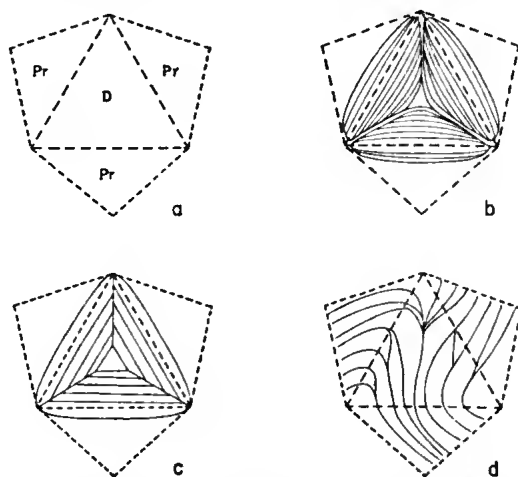


FIG. 1.—Schematic distribution and orientation of sculptural elements (muri) in Australian *Cicatricosisporites*. a, Illustrative method (Pr = proximal surface, D = distal surface). b, *C. australiensis* (Cookson) Potonié 1956 and *C. ludbrookii* Dettmann 1963. c, *C. hughesi* Dettmann 1963 and *C. pseudotripartitus* (Bolikhovitina) Dettmann 1963. d, *C. cuneiformis* Pocock 1965. Note: Size of spores and muri not to scale.

of *Cicatricosisporites*. Sculptural patterns of these fall into three groups based upon orientation of muri and/or the nature in which the mural series coalesce or terminate. It can also be noted that species illustrated in Fig. 1b, c, are radially symmetrical; and that in Fig. 1d has bilateral symmetry. It seems possible that symmetry characteristics may enable objective subdivision of the genus.

DISTRIBUTION OF *CICATRICOSISPORITES* IN AUSTRALIA: The precise lower age limit of Australian *Cicatricosisporites* is difficult to establish because most

initial appearances of this genus are in strata that lack associated faunal control. In eastern Australia the earliest occurrences are in non-marine sequences that may be either uppermost Jurassic or lowermost Cretaceous in age. To the north, in Papua, Evans (1966b) recorded *Cicatricosisporites* in beds containing a Neocomian fauna, and in immediately underlying sediments. From the Canning Basin, Western Australia, Balme (1957) and Evans (in Henderson, Condon, & Bastian 1963) report the genus at horizons immediately overlying strata containing *Buchia subpallasi* (Krumbeck) and considered to be no younger than Kimmeridgian (Veevers & Wells 1961). Further, Mr. B. E. Balme (pers. comm.) has observed forms referable to *Cicatricosisporites* in Upper Jurassic sediments of the Carnarvon Basin (subsurface Barrow Island). Thus in Western Australia at least, the genus makes its initial appearance during late Jurassic times.

The first representatives to appear in eastern Australia are *C. australiensis* and *C. ludbrookii* Dettmann 1963; during the Aptian these are joined by *C. hughesi* Dettmann 1963. In Middle-Upper Albian times several other forms are introduced including *C. pseudotripartitus* (Bolkhovitina) Dettmann 1963 and *C. cuneiformis* Pocock 1965; these are sometimes associated with the inception of *Appendicisporites*.

Cicatricosisporites attains maximum abundance and diversity in late Albian and possibly early Cenomanian times. Its post-Cenomanian occurrences have been documented only in the Otway Basin, where it is infrequent in Turonian and early Senonian sediments. Isolated examples of the genus do occur in the post-Senonian sequence of the Otway Basin but these differ in physical condition (e.g. exine preservation) from the associated forms and are regarded as having been recycled. Moreover they are often accompanied by reworked Permian, Triassic, and early Cretaceous types. Thus it is probable that in Australia, *Cicatricosisporites* did not survive the Senonian.

***Cicatricosisporites cuneiformis* Pocock 1965**

(Pl. 6, fig. 3-5; Fig. 1d)

DESCRIPTION: Microspores trilete, biconvex; amb convexly subtriangular to circular. Laesurae straight, length one-half to three-quarters of spore radius, lipped; lips comprise elevated exinal extensions, $3-4\mu$ high at pole, tapering towards termini of laesurae. Exine $1-1.5\mu$ thick with distal and proximal cicatricose sculpture. Distal sculpture bilaterally symmetrical, comprising a parallel series of muri; muri converge towards equatorial interradial regions and cross equator at 45° angle, to terminate at laesurate margins of each contact face. Proximal sculpture radially arranged. Muri $1.5-2\mu$ wide, ca. 1μ high with rounded crests; separated by lumina $1-1.5\mu$ wide. Total span of 4 muri and lumina is $9-11\mu$ in equatorial interradial regions.

DIMENSIONS: Equatorial diameter 41 (50) 60μ ; polar diameter (2 specimens) 32, 35μ .

REMARKS AND COMPARISON: The species exhibits overall bilateral symmetry, with a radiosymmetrical proximal face, and a bilaterally symmetrical distal face (Fig. 1d). The sculptural pattern conforms with that depicted by Deák (1963) in her fig. 1. Other forms having similar sculptural and symmetry attributes include Deák's (1963) species *Cicatricosisporites venustus* and *C. furcatus*; the specimens assigned by Pocock (1965) to *C. tersa* (Kara-Murza) and *C. mediotriatus* (Bolkhovitina); and forms that Brenner (1963) illustrated as *C. dorogensis* Potonić & Gelletich and *C. hallei* Delcourt & Sprumont. *C. cuneiformis* Pocock is distinct from these forms however in its size, in the size and shape of muri and lu-

mina and also in the development and extension of laesurate lips. The species may be conspecific with forms allocated by Hedlund (1966, Pl. 3, fig. 5a, b) to *C. dorogensis*.

DISTRIBUTION: The species was described from late Middle Albian strata of Canada (Pocock 1965); similar forms illustrated by Hedlund (1966) are from the Cenomanian of Oklahoma. Although rarely common, the species is widely distributed in Australia in younger horizons of the *Coptospora paradoxa* Zone, and in the *Tricolpites pannosus* and *Appendicisporites distocarinatus* Zones; it is a rare constituent of the *Clavifera triplex* Zone.

Genus *Balmeisporites* Cookson & Dettmann 1958

TYPE SPECIES (by original designation): *Balmeisporites holodictyus* Cookson & Dettmann 1958.

Balmeisporites glenelgensis Cookson & Dettmann 1958

(Pl. 8, fig. 1)

1958 *Balmeisporites glenelgensis* Cookson & Dettmann, p. 43; Pl. 2, fig. 9, 10. [1958a]

1963 *Balmeisporites auriculatus* Hall, p. 433-34; Pl. 5, fig. 12-15.

DIMENSIONS: Equatorial diameter 83 (105) 123 μ ; overall polar diameter 101 (123) 150 μ .

REMARKS: Hall (1963) distinguished his *Balmeisporites auriculatus* from *B. glenelgensis* on slight differences in the size of the mesh formed by the surface reticulum, and on the shape of the equatorial projections. However, such small variations fall within the morphographical range of Australian specimens referred to *B. glenelgensis*.

DISTRIBUTION: Known from the Great Artesian and Otway Basins, eastern Australia, as a component of the *Appendicisporites distocarinatus*, *Clavifera triplex*, and *Tricolpites pachyexinus* Zones (Cookson & Dettmann 1958a; Evans 1962, 1964; Dettmann 1963). Extra-Australian occurrences include Turonian of eastern Siberia (Mtschedlishvili & Samoilovich 1962, 1965), and Cenomanian of Iowa (Hall 1963) and Oklahoma (Hedlund 1966).

Subturma ZONOTRILETES Waltz 1935

Infraturma AURICULATI Schopf emend. Dettmann 1963

Genus *Appendicisporites* Weyland & Krieger 1953

SELECTED SYNONYMY:

1949 *Plicatella* Malyavkina (*pars*), *nom. nud.*, p. 60.

1953 *Appendicisporites* Weyland & Krieger, p. 12.

1960 *Plicatella* Malyavkina ex Potonié, p. 50.

TYPE SPECIES (by original designation): *Appendicisporites tricuspidatus* Weyland & Griefeld 1953.

DISCUSSION: This genus was validly instituted by Weyland & Krieger (1953) and incorporates trilete spores having a cicatricose sculpture of one or several sets of parallel muri together with exinal thickenings (appendices) in the equatorial radial regions. The type species possesses three sets of muri that parallel the equator and fuse to form an appendix at each equatorial radial position.

Plicatella was proposed by Malyavkina (1949) but remained invalid until 1960 when Potonié selected a type species, *P. tricacantha* Malyavkina 1949. The latter has all the diagnostic characters of *Appendicisporites*, but Potonié argued that the two genera are separable according to relative length and shape of the equatorial

appendices. The present authors do not regard such criteria as providing a sufficiently objective basis for the retention of *Plicatella*.

It should be noted that the type materials of *Appendicisporites* and *Plicatella* have not been illustrated or described in lateral aspect, an orientation which shows most clearly the precise form and extent of the appendices. As illustrated in lateral aspect, the Australian spores here allocated to *Appendicisporites* possess fin-like appendices that are developed in the disto-equatorial regions. In full polar views these appendices appear to be conical in shape and simulate purely equatorial, not distal developments. Several authors (e.g. Bolkhovitina 1961, Markova in Samoilovich *et al.* 1961, Pockock 1965, Burger 1966, Norris 1967) illustrate and describe in varying detail the shape of the appendices as seen in both polar and equatorial aspects, but the great majority of species attributable to *Appendicisporites* are known only in polar aspects.

Appendicisporites is similar in morphology to the spores produced by some extant species of the schizaeaceous fern *Anemia* Swartz, such as those of *A. glareosa* Gardn. (see Bolkhovitina 1961, Pl. 9, fig. 3a-c). In view of this, some authors have indiscriminately applied *Anemia* to dispersed plant microfossils of the *Appendicisporites* type. The spores found in the Cretaceous schizaeaceous megafossil *Pelletieria valdensis* Seward (see Hughes & Moody-Stuart 1966) appear to be comparable to *Appendicisporites* as discussed herein, notably in the development of exinal thickening in equatorial radial and distal regions. Hughes & Moody-Stuart believe however that the thickenings shown by their illustrated forms are due largely to compression during diagenesis. The thickenings of the species described below are considered to be a primary characteristic of the exine; accordingly the form is appropriately assigned to *Appendicisporites*.

DISTRIBUTION OF APPENDICISPORITES IN AUSTRALIA: Spores comparable to *Appendicisporites* are unknown in pre-Middle Albian Australian deposits. Their first appearance in the southern Eromanga Basin is within upper Albian?Cenomanian horizons of the Oodnadatta Formation. They also occur in the Styx Coal Measures of Queensland, which on micro- and megafossil evidence are of Upper (or possibly Middle) Albian age. In the Otway Basin the genus appears initially in association with Upper Albian microfloras and ranges into sediments of Turonian and early Senonian age, but apparently no higher.

Appendicisporites has been reported from Papua (Evans 1966b) in sediments that could be as old as the Lower Albian; and, from the same area, we have observed a variety of representatives in Omati No. 1 well, sample 2, the age of which is Albian (Cookson & Dettmann 1958b).

***Appendicisporites distocarinatus* sp. nov.**

(Pl. 6, fig. 13-20)

DIAGNOSIS: Microspores trilete, biconvex, with strongly arched distal surface; amb convexly subtriangular; semicircular in equatorial view. Laesurae straight, three-quarters radius of amb; enclosed within membraneous lips, $3-4\mu$ high. Exine $1.5-2\mu$ thick, thicker ($4-8\mu$) in disto-equatorial radial regions where 3 fin-like exinal projections are developed. Projections highest and widest at equator (up to 8μ high, $3-4\mu$ wide) tapering in both height and width to within $14-17\mu$ of distal pole where they are absent. Distal and equatorial exine sculptured with 3 series of 7-10 muri disposed parallel to equator and coalescing with thickened projections in disto-equatorial radial regions. Muri have straight or tapering sides ($1.5-2\mu$ high) and flat crests; equal in width or slightly wider ($2-2.5\mu$) than adjacent

lumina ($1.5-2.5\mu$). Four muri and intervening lumina span $14-17\mu$. Contact faces smooth.

DIMENSIONS: Equatorial diameter (including projections) 41 (57) 75μ ; polar diameter (11 specimens) 27 (41) 49μ .

HOLOTYPE: Preparation F270/5, 41.7 114.6 , GSV 61871. Pl. 6, fig. 16-18. Distal aspect. Amb convexly triangular, diameter 55μ ; laesurae 22μ long; sculpture of 3 series of 8 parallel muri, each murus 2μ wide, 1.5μ high, spaced 2μ apart; 4 muri and lumina span 15μ in distal interrarial region; fin-like projections 24μ long, 6μ high and 5μ wide at equator; exine 1.5 thick in equatorial interrarial region.

TYPE LOCALITY: Victoria, F.B.H. Fergusons Hill No. 1 well, at 2427-37 ft (core 5).

COMPARISON: A close sculptural resemblance is evident between this species and the spores assigned to *Appendicisporites tricornitatus* Weyland & Griefeld 1953 by Hedlund (1966), Pl. 4, fig. 4a, b) and by Singh (1964, Pl. 2, fig. 1). However, the form and extent of the appendices of the latter specimens are not precisely known, thus precluding accurate comparison with *A. distocarinatus* sp. nov. The type of *A. erdmanii* Pocock 1965 appears to be similar to the Australian species in arrangement of muri and in form of the fin-like appendices, but has considerably wider (up to 4μ) muri and narrower (1μ) lumina. Other similar forms include *A. potomacensis* Brenner 1963, which has more strongly developed proximal sculpture and wider spaced muri; *A. stylosus* (Thiergart) Deák 1963, which has broader, closely spaced muri and higher disto-equatorial appendices; *Plicatella problematica* Burger 1966, which has considerably higher ($4-5\mu$) muri; and *Anemia macrorhyza* (Malyavkina) Bolkhovitina 1953, which, as described by Bolkhovitina (1961) and Markova (in Samoilovich *et al.* 1961), possesses sculpture on the contact faces.

DISTRIBUTION: Sometimes common in the *Tricolpites pannosus* and *Appendicisporites distocarinatus* Zones, rarely present in the uppermost part of the *Coptospora paradoxa* Zone. Evans (1966b, Pl. 1, fig. 4) has figured a possible representative of this species from his *Odontochitina operculata* Zone (Albian) at Archer River, Papua.

Infraturma TRICRASSATI Dettmann 1963

Genus *Clavifera* Bolkhovitina 1966

1953 *Gleichenia* Smith: Bolkhovitina (*pars*) p. 53-5.

1959 *Gleichenioidites* Ross subgenus *Triplexisporis* Krutzsch, p. 114.

1961 *Gleichenioidites* Grigorjeva (*pars*) in Samoilovich *et al.*, p. 59-63.
[non *Gleichenioidites* Ross]

1966 *Clavifera* Bolkhovitina, p. 68.

TYPE SPECIES (by original designation): *Clavifera triplex* (Bolkhovitina) Bolkhovitina 1966.

DISCUSSION: Bolkhovitina's (1966) diagnosis of this genus embraces gleicheniaceous-type trilete spores having essentially smooth exines in which radial and interrarial thickenings (distinct from one another) are developed equatorially. These features are displayed by the Australian spores here allocated to the type species. However, as discussed subsequently, the exine is probably only weakly thickened in the equatorial radial regions; the apparent strong development of radial thickening appears to be related to the shape characteristics of the distal surface.

As the subgenus *Triplexisporis* Krutzsch 1959 has not been elevated to generic status, the correct name for the spores at generic level is *Clavifera*. Bolkhovitina notes that *Gleicheniidites* Ross ex Delcourt & Sprumont 1955 lacks radial thickenings at the equator and as such is separable from her *Clavifera*. She suggests affinity between *Clavifera* and extant members of the Gleichenioideae on the grounds of spore morphology.

***Clavifera triplex* (Bolkhovitina) Bolkhovitina 1966**
(Pl. 6, fig. 6-8)

SELECTED SYNONYMY:

- 1953 *Gleichenia triplex* Bolkhovitina, p. 54; Pl. 8, fig. 10-13.
1959 *Gleicheniidites (Triplexisporis) triplex* (Bolkhovitina) Krutzsch, p. 114.
1961 *Gleicheniidites triplex* (Bolkhovitina) Grigorjeva in Samoilovich *et al.*, p. 63; Pl. 16, fig. 8-10.
1966 *Clavifera triplex* (Bolkhovitina) Bolkhovitina, p. 68; Pl. 1, fig. 6 a-c.

DESCRIPTION: Microspores trilete; distal surface strongly arched or flattened with 3 arcuate folds that project beyond equator giving 'knobbed' or bulbous appearance to amb apices; proximal surface pyramidal. Amb triangular with straight or slightly concave sides. Laesurae straight, length approximately equal to spore radius; with membranous lips 1-2 μ high. Exine 1-2 μ thick, thicker at equator. Equatorial thickenings constitute interrarial crassitudes, 4-6 μ wide, with sinuous periphery. In equatorial radial regions exine is also slightly thickened; here the true degree of thickening is best observed in specimens lacking distal arcuate folds (i.e. in relatively uncompressed examples). Specimens with well-developed distal folds show an apparently abrupt thickening at each amb apex; these 'thickenings' are, however, exaggerated in polar view by oblique optical sections through the distal arcuate folds. Proximal exine smooth adjacent to laesurae; faintly scabrate in semi-circular area located in each equatorial interrarial region. Distal exine smooth.

DIMENSIONS: Equatorial diameter 27 (39) 49 μ .

COMPARISON AND AFFINITY: The Australian specimens described above appear to be identical with *Clavifera triplex* (Bolkhovitina) Bolkhovitina 1966 as originally diagnosed and as reported by Grigorjeva (in Samoilovich *et al.* 1961) and Döring (1965). '*Gleicheniidites posttriplex* Döring 1965 appears to differ from *C. triplex* only in shape, a feature which Skarby (1964) considers to be unreliable in the discrimination between gleicheniaceous spore species. Wider interrarial crassitudes and the presence of thickening at amb apices distinguish *C. triplex* from spores assigned by Balme (1957) and Dettmann (1963) to *Gleicheniidites* cf. *G. circinidites* (Cookson) Dettmann 1963.

On the basis of spore morphology, Bolkhovitina (1966) allies *C. triplex* with the extant Gleichenioideae, in particular with *Dicranopteris rigida* (Kunze) Nakai.

DISTRIBUTION: Widely distributed in U.S.S.R. with records from Aptian-Paleocene sediments (Bolkhovitina 1953, 1966; Samoilovich *et al.* 1961). Döring (1965) reports *C. triplex* from the German Neocomian. In the eastern Australian Cretaceous the species is a consistent component of the *Clavifera triplex* Zone with less frequent representation in the *Tricolpites pachyexinus* Zone and in sediments containing the *Nothofagidites* Microflora.

Genus *Ornamentifera* Bolkhovitina 1966

- 1953 *Gleichenia* Smith: Bolkhovitina (*pars*), p. 53-5.
1959 *Gleicheniidites* Ross subgenus *Peregrinisporis* Krutzsch, p. 114.

- 1961 *Gleichenioidites* Grigorjeva (*pars*) in Samoilovich *et al.*, p. 59-63. [non *Gleichenioidites* Ross]
1966 *Ornamentifera* Bolkhovitina, p. 69.

TYPE SPECIES (by original designation): *Ornamentifera echinata* (Bolkhovitina) Bolkhovitina 1966.

DISCUSSION: *Ornamentifera* was diagnosed by Bolkhovitina (1966) to incorporate trilete spores of presumed gleicheniaceous affinity, having interrarial thickenings at the equator and sculptural projections of spinae, coni, &c. Morphologically comparable types had previously been allocated to the extant plant genus *Gleichenia* Smith by Bolkhovitina (1953 and later); to the subgeneric category *Peregrinisporis* by Krutzsch (1959) and Döring (1965); and to *Gleichenioidites* Grigorjeva (non Ross) by Grigorjeva in Samoilovich *et al.* (1961). Of these spore taxa, only *Ornamentifera* bears a correct generic name, because *Peregrinisporis* has subgeneric status, and *Gleichenioidites* Grigorjeva is a later homonym of *Gleichenioidites* Ross ex Delcourt & Sprumont 1955 (see Dettmann 1963, p. 65; Skarby 1964, p. 64).

The type species of *Ornamentifera*, *O. echinata* (Bolkhovitina) Bolkhovitina 1966, which is also the designated type of *Gleichenioidites* Grigorjeva, is regarded by Skarby (1964, p. 64) as being 'very similar to the spore (sic) described by Ross as *Anemioidites echinatus* (1949, p. 32; Pl. 1, fig. 17-18)'. If in fact these two forms prove to be identical then *O. echinata* (Bolkhovitina) is both a later homonym and synonym of Ross's species; and *Anemioidites* Ross 1949 would have priority over *Ornamentifera* Bolkhovitina 1966. However it should be noted that Ross's illustrations do not convincingly show equatorial interrarial thickenings and as morphological doubt exists *Ornamentifera* is used herein.

The type of *Trubasporites* Vavrdova 1964 differs from *Ornamentifera* in having a foveolate exine.

***Ornamentifera sentosa* sp. nov.**

(Pl. 6, fig. 9-12)

DIAGNOSIS: Microspores trilete, tricarassate, biconvex, the distal surface strongly arched. Amb triangular with straight or slightly concave sides and acutely rounded angles. Laesurae straight, length approximating spore radius, with membranous lips, 1-2 μ high. Exine 2-3 μ thick, thicker at interrarial regions of equator where 5-8 μ broad crassitudes are developed. Crassitudes have distinctly serrate equatorial margins. Proximal contact areas bear diverse, usually coalescent sculptural elevations with flat, rounded, or pointed crests (2-3 μ high) and irregular bases (2-6 μ in diameter); elevations thus comprise verrucae, rugulae, spinac, and bacula. On distal surface, similar coalescent sculptural elevations are developed but confined to a concavely triangular area which has its centre at the pole and its apices in the equatorial radial regions.

DIMENSIONS: Equatorial diameter 36 (43) 52 μ .

HOLOTYPE: Preparation F368/6, 37.1 119.8, GSV 61867. Pl. 6, fig. 11, 12. Proximal aspect. Amb triangular, diameter 44 μ ; laesurae 22 μ long; proximal (contact) areas with discrete or coalescent, irregularly based sculptural projections, 1-5 μ in basal diameter; distal exine sculptured with coalescent elevations in a triangular polar area, the sides of which parallel amb; equatorial crassitudes 6 μ in maximum width, margins incised.

TYPE LOCALITY: Victoria, F.B.H. Port Campbell No. 4 well at 3821-38 ft (core 7).

COMPARISON: Species assigned by Bolkhovitina (1966) to *Ornamentifera* possess sculptural projections (spinae, conii, grana) that are discrete and uniformly distributed, and are thus distinct from *O. sentosa* sp. nov. with its differentially distributed, coalescent sculptural elements. Döring's (1965) species *Trubasporites nudowensis* and *T. verrutorosus* occasionally have coalescent projections but these constitute verrucae and rugulae with rounded crests. *Gleicheniidites* (*Peregriniisporis*) f. sp. A. of Döring (1965) has less conspicuous equatorial thickening than *O. sentosa* and its distal sculpture is uniformly distributed.

DISTRIBUTION: The species is restricted to horizons of the *Tricolpites pachyexinus* Zone and those containing the *Nothofagidites* Microflora.

Genus **Camarozonosporites** Pant ex Potonié 1956 emend. Klaus 1960

TYPE SPECIES (by subsequent designation of Potonié 1956, p. 65): *Camarozonosporites cretaceus* (Weyland & Krieger) Potonié 1956.

DISCUSSION: The type species is clearly trierassate (thickened in the equatorial interrational regions) although its sculptural features have not yet been fully described or clearly illustrated. Klaus regarded the genus as rugulate distally and with reduced proximal sculpture; this emendation is followed here. Krutzsch (1959) used the genus in a similar sense and later (1963a) recognized that his *Hamulatisporis* is synonymous with Klaus's emended version of *Camarozonosporites*.

Of the Australian spores here referred to *Camarozonosporites* those of *C. amplus* (Stanley) comb. nov. and *C. ohaiensis* (Couper) comb. nov. show only slight exinal thickening in their equatorial radial regions. The other species, *C. bullatus* Harris 1965, recorded by us from the Victorian Upper Cretaceous sequence, has strongly thickened interrational crassitudes, but its distal exine possesses features not explicitly diagnosed for *Camarozonosporites*.

Camarozonosporites amplus (Stanley) comb. nov.

(Pl. 7, fig. 1-3)

1965 *Rugulatisporites* sp. indet.: Harris, Pl. 25, fig. 12 (no description). [1965a]

1965 *Hamulatisporis amplus* Stanley, p. 242; Pl. 29, fig. 1-6.

1966 *Perotrillites rugulatus* Couper: Gray & Groot, p. 124; Pl. 42, fig. 13, 14.

DESCRIPTION: Microspores trilete, biconvex; amb convexly subtriangular to circular. Laesurae straight, length at least three-quarters spore radius. Exine 2-3 μ thick; thicker in equatorial interrational regions where narrow (3-6 μ) crassitudes are developed. Distal and equatorial exine sculptured with low, strongly sinuous elevations (rugulae) that occasionally anastomose to enclose irregularly elongate lumina 2-8 μ in maximum length; elevations 3-4 μ broad at base, 1-2 μ high, with broadly rounded crests. Circular area (diameter 6-8 μ) about distal pole devoid of rugulae but with coarse grana. Proximal sculpture consists of low (ca. 1 μ high), narrow (1-2 μ wide) elongate sinuous elevations that emanate from laesurate margins and occasionally bifurcate towards equator.

DIMENSIONS: Equatorial diameter 55 (73) 109 μ .

REMARKS AND COMPARISON: The holotype (Stanley 1965, Pl. 29, fig. 1-3) is situated in an off-polar aspect, but its illustrations show the narrow interrational crassitudes and a circular granulate area of exine in the distal polar region. Closely comparable features are exhibited by the specimens here assigned to the species.

Camarozonosporites helenensis Krutzsch 1963 and *Lygodium reticulatiformis*

Bolkhovitina 1961 may be conspecific with *C. amplus* (Stanley) comb. nov., but neither species apparently is granulate about the distal pole. *C. amplus* is distinct from *Perotrilites rugulatus* Couper 1958 which has a thicker exine and narrower flat-topped rugulae; and from *C. hammenii* van Ameron 1965 which has a stronger development of equatorial thickening.

AFFINITY: *C. amplus* is morphologically similar to extant *Lycopodium* spores belonging to Group V of Harris (1955).

DISTRIBUTION: Previously recorded from late Upper Cretaceous and Lower Paleocene of Dakota (Stanley 1965), Senonian of Delaware and New Jersey (Gray & Groot 1966), and Middle Paleocene of Australia (Harris 1965a). The similar forms described by Krutzsch (1963a) and Bolkhovitina (1961) are from Oligocene-Pliocene of Europe and Santonian of Kazakhstan respectively. Although rarely abundant, *C. amplus* is almost invariably a constituent of the *Tricolpites pachyexinus* Zone and of the *Nothofagidites* Microflora.

***Camarozonosporites ohaiensis* (Couper) comb. nov.**

(Pl. 7, fig. 6, 7)

1953 *Trilites ohaiensis* Couper (*pro parte*), p. 30; Pl. 3, fig. 23.

1960 *Trilites ohaiensis* Couper emend. Couper, p. 41; Pl. 2, fig. 7, 8 (Emendation based upon type and additional specimens. [1960a])

DESCRIPTION: Microspores trilete, biconvex; amb subcircular to circular. Laesurae straight, extending about half the distance to equator. Exine $1.5-3\mu$ thick; differentially thickened at equator where narrow ($3-5\mu$ wide) interrational crassitudes are developed. Distal and equatorial exine with low ($1-2\mu$ high), narrow ($1-2\mu$ broad), closely spaced, sinuous rugulae that occasionally anastomose to enclose irregularly elongate lumina $2-5\mu$ in length. Circular area ($10-12\mu$ in diameter) about distal pole devoid of rugulae but granulate. Proximal exine with markedly reduced rugulate sculpture.

DIMENSIONS: Equatorial diameter 60 (75) 99μ .

COMPARISON AND AFFINITIES: The species differs from *Camarozonosporites amplus* (Stanley) comb. nov. in possessing relatively shorter laesurae and narrower, more closely spaced sculptural elevations. The large size and narrow interrational crassitudes enable distinction of *C. ohaiensis* (Couper) comb. nov. from other members of the genus. *Lycopodium*-spores assigned to Harris's (1955) Group V display similar sculptural and equatorial features.

DISTRIBUTION: Described originally from New Zealand where it is apparently restricted to sediments of probable Senonian and Maestrichtian age (Couper 1960a, p. 41; table 2). *C. ohaiensis* is a rare component of the *Tricolpites pachyexinus* Zone and of the *Nothofagidites* Microflora.

***Camarozonosporites bullatus* Harris 1965**

(Pl. 7, fig. 4, 5)

1965 *Camarozonosporites bullatus* Harris, p. 82; Pl. 26, fig. 2, 3. [1965a]

1965 Gen. et sp. indet. Harris, Pl. 25, fig. 20 (no description). [1965a]

DESCRIPTION: Microspores trilete, biconvex; amb convexly subtriangular. Laesurae straight, length three-quarters spore radius, lipped; lips constitute low, $3-4\mu$ wide exinal thickenings. Exine conspicuously tricarassate at equator; crassitudes $9-14\mu$ wide in interrational regions, narrowing to 4μ at radii. Distal exine with a set of 3 low muri ($3-5\mu$ wide) that parallel sides of spore cavity and coalesce radially to enclose a triangular to subcircular area (diameter $12-20\mu$)

about distal pole. Distal polar exine thickened with a small circular crassitude $3-5\mu$ in diameter. Exine otherwise smooth or faintly scabrate.

DIMENSIONS (10 specimens): Overall equatorial diameter 45 (57) 69μ ; diameter of spore cavity 36 (43) 55μ .

REMARKS AND COMPARISON: The distal elevations that enclose a triangular to subcircular area in which a polar crassitude is developed are clearly evident in the holotype (Harris 1965a, Pl. 26, fig. 3) and in another specimen illustrated by Harris (Pl. 25, fig. 20) that is here assigned to *Camarozonosporites bullatus*.

Retitriletes triradiatus Pierce 1961 (p. 30; Pl. 1, fig. 18) strongly resembles *C. bullatus*, such that the two species may well prove to be conspecific.

The species is not altogether conformable with *Camarozonosporites* as emended by Klaus (1960). Assignment to *Coronatispora* Dettmann 1963 or *Zebbrasporites* Klaus 1960 was considered but the former is characterized by comprehensive foveolate-reticulate sculpture, and the latter has radially arranged distal elevations.

AFFINITY: Harris (1965a) suggested a morphological resemblance to spores of *Lycopodium*.

DISTRIBUTION: Described from the Middle Paleocene of western Victoria (Harris 1965a) and recorded (Harris 1965b) from the Lower Tertiary of Queensland. In the present study it was found in the Otway Basin in sediments containing the late Cretaceous *Nothofagidites* Microflora. The similar spores of *Retitriletes triradiatus* occur in the early Upper Cretaceous of Minnesota (Pierce 1961).

Infraturma CINGULATI Potonié & Klaus emend. Dettmann 1963

Genus *Kraeuselisporites* Leschik emend. Jansonius 1962

TYPE SPECIES (by original designation): *Kraeuselisporites dentatus* Leschik 1955.

***Kraeuselisporites jubatus* sp. nov.**

(Pl. 7, fig. 8-12)

DIAGNOSIS: Microspores trilete, zonate, biconvex; amb convexly subtriangular to subcircular. Spore cavity outline (polar view) triangular with straight to slightly convex sides. Laesurae straight, more or less reaching equator, with membranous lips that are highest at pole ($16-20\mu$) and have finely serrate crests. Exine $1-2\mu$ thick, smooth to faintly scabrate proximally and distally. Distal exine additionally sculptured with $3-6\mu$ high, membranous muri that have strongly spinose crests; spine-like elements $2-3\mu$ high, $1-3\mu$ in maximum basal diameter. Muri anastomose about pole to delimit 1 to 5 pentagonal-hexagonal lumina (diameter $10-20\mu$), freely terminate towards inner margin of zona. Zona membranous, $14-25\mu$ wide (uniformly wide on given specimen), faintly scabrate, equatorial margin finely serrate.

DIMENSIONS: Overall equatorial diameter 70 (85) 110μ ; diameter of spore cavity 41 (48) 60μ . Polar diameter (2 specimens) 46μ , 49μ .

HOLOTYPE: Preparation F235/1, 47.4 119.9, GSV 61879. Pl. 7, fig. 10, 11. Distal aspect. Amb subcircular, diameter 74μ ; spore cavity convexly triangular, diameter 49μ ; laesurae straight, 27μ long, with membranous elevated lips; distal reticulum of high (up to 11μ), membranous muri having deeply incised crests;

muri anastomose to form one lumen surrounding pole and terminate freely in radial regions near inner margin of zona.

TYPE LOCALITY: Victoria, Mines Dept. Vic. Timboon No. 5 bore, 3500-04 ft (core BB).

COMPARISON: The species differs from *Kraeuselisporites majus* (Cookson & Dettmann) Dettmann 1963 in being larger and in having high, widely spaced, membranous muri that enclose one or several lumina in the distal polar area.

DISTRIBUTION: Present, and sometimes common, in the *Tricolpites pannosus* and *Appendicisporites distocarinatus* Zones; infrequent in the *Clavifera triplex* Zone and the uppermost horizons of the *Coptospora paradoxa* Zone.

TURMA MONOLETES Ibrahim 1933

Suprasubturma ACAVATOMONOLETES Dettmann 1963

Subturma AZONOMONOLETES Lubert 1935

Infraturma LAEVIGATOMONOLETI Dybová & Jachowicz 1957

Genus *Laevigatosporites* Ibrahim 1933

TYPE SPECIES (by original designation): *Laevigatosporites vulgaris* (Ibrahim) Ibrahim 1933.

Laevigatosporites major (Cookson) Krutzsch 1959
(Pl. 8, fig. 2)

For synonymy see Harris 1965a, p. 83.

DIMENSIONS: Equatorial diameter: length 52 (65) 74 μ , breadth 38 (45) 50 μ . Polar diameter 30 (42) 49 μ .

DISTRIBUTION: First appearances in the uppermost part of the *Coptospora paradoxa* Zone; infrequent throughout the Upper Cretaceous. Cookson (1947) and Harris (1965a) report the species from the Lower Tertiary of Kerguelen and Victoria respectively.

TURMA HILATES Dettmann 1963

Genus ***Aequitriradites*** Delcourt & Sprumont emend.
Cookson & Dettmann 1961

TYPE SPECIES (by original designation): *Aequitriradites dubius* Delcourt & Sprumont emend. Delcourt, Dettmann, & Hughes 1963.

Aequitriradites hispidus sp. nov.
(Pl. 7, fig. 13)

1963 *Aequitriradites* sp. Dettmann, p. 95; Pl. 22, fig. 14, 15.

DIAGNOSIS (Dettmann 1963, p. 95): 'Microspores zonate; inaperturate or hilate; amb of spore cavity triangular with straight sides. Exine 2.5-3 μ thick; distal polar exine composed of discrete, polygonal-based (2-3 μ diameter), low (2 μ high) coni and may be ruptured (hilate); remainder of exine sculptured with small (1 μ basal diameter, 1-2 μ high), sparsely disposed spinules. Zona membranous, 14-17 μ wide, irregular in outline. Tetrad mark occasionally present in form of narrow, low ridges which extend from equator to just beyond inner margin of zona'.

DIMENSIONS (15 specimens): Overall equatorial diameter 70 (83) 100 μ ; diameter of spore cavity 55 (66) 78 μ .

HOLOTYPE: The specimen illustrated by Dettmann (1963, Pl. 22, fig. 15) and in present study is here designated the holotype. Preparation D234/5, P22136. Distal aspect. Amb irregular, diameter 98 μ ; spore cavity diameter 78 μ , outline triangular; exine 3 μ thick, spinulate except in an area (15 μ in diameter) about distal pole where discrete polygonal-based coni are developed; tetrad mark comprises low ridges extending from equator 5-7 μ towards pole; zona membranous.

TYPE LOCALITY: South Australia, Kopperamanna No. 1 bore, at 2970 ft.

COMPARISON: This species differs from others assigned to *Aequitriradites* in its larger size and sculptural details, and in having a spore cavity that is triangular in polar view.

DISTRIBUTION: Known only from the *Crybelosporites stylosus* Zone of the Lake Frome Embayment, Eromanga Basin, and Surat Basin (Dettmann 1963; Evans 1966c; present study).

ANTETURMA POLLENITES Potonić 1931

TURMA SACCITES Erdtman 1947

Subturma DISACCITES Cookson 1947

Genus *Dacrydiumites* Cookson ex Harris 1965

TYPE SPECIES (by subsequent designation of Harris 1965a, p. 86): *Dacrydiumites florinii* Cookson & Pike 1953.

Dacrydiumites florinii Cookson & Pike 1953

(Pl. 8, fig. 3)

DIMENSIONS: Corpus: breadth 30 (38) 44 μ ; length 34 (42) 50 μ ; depth 25 (32) 37 μ . Saccus: breadth 17 (22) 25 μ ; length 25 (32) 39 μ .

DISTRIBUTION: Uncommon in the Upper Cretaceous of the Otway Basin, where it is observed in upper horizons containing the *Nothofagidites* Microflora. Evans (1966a, p. 27) notes a slightly older occurrence 'within or just before' his *Xenikoon australis* Zone, i.e. within the oldest horizons that have yielded the *Nothofagidites* Microflora. *D. florinii* occurs sometimes frequently in the Australian Tertiary (Cookson & Pike 1953, Harris 1965a).

Genus *Phyllocladidites* Cookson ex Couper 1953

TYPE SPECIES (by subsequent designation of Couper 1953, p. 38): *Phyllocladidites mawsonii* Cookson 1947.

Phyllocladidites mawsonii Cookson 1947

(Pl. 8, fig. 4)

DIMENSIONS: Corpus: breadth 22 (30) 42 μ ; length 22 (31) 39 μ ; depth 20 (25) 31 μ . Saccus: breadth 8 (11) 14 μ ; length 12 (14) 17 μ .

REMARKS: The Upper Cretaceous pollen here assigned to *Phyllocladidites mawsonii* Cookson appear to be comparable to the species as diagnosed by Cookson and as used by Couper (1953, 1960a) and Harris (1965a). They are smaller than, and lack the well-defined saccus reticulum of, *P. reticulosaccatus* Harris 1965.

DISTRIBUTION: In its initial south-eastern Australian appearances the species is associated with foraminiferal Zonule B of Taylor (1964). Within this zonule it

has wide distribution in the Otway Basin. It becomes increasingly common in Senonian and later strata, assuming importance in Lower Tertiary sediments (Cookson 1953a, Harris 1965a). Extra-Australian occurrences include Lower Tertiary of Kerguelen (Cookson 1947); Senonian and Lower Tertiary of Antarctica (Cranwell 1964, fig. 2); and Senonian-Eocene or Oligocene of New Zealand (Couper 1953, 1960a).

TURMA PLICATES Naumova. emend. Potonié 1960

Subturma TRIPTYCHES Naumova emend. Potonié 1960

Genus **Tricolpites** Cookson ex Couper 1953

TYPE SPECIES (by subsequent designation of Couper 1953, p. 61): *Tricolpites reticulatus* Cookson 1947.

DISCUSSION: The genus is used here in Couper's (1953) sense for tricolpate grains having variable size, shape, and sculptural features.

Tricolpites pachyexinus Couper 1953

(Pl. 8, fig. 9, 10)

DIMENSIONS: Equatorial diameter 20 (24) 31 μ .

REMARKS: The Australian grains here referred to *Tricolpites pachyexinus* Couper are somewhat smaller and have a generally thinner exine (1.5-3.0 μ) than those described by Couper (1953, 1960a).

DISTRIBUTION: Rarely abundant, but a consistent element of Australian Upper Cretaceous assemblages of the *Tricolpites pachyexinus* Zone and the *Nothofagidites* Microflora. Couper (1953, 1960a) emphasizes the stratigraphic significance of the species (Senonian, Maestrichtian, and Danian of New Zealand).

Tricolpites gillii Cookson 1957

(Pl. 8, fig. 14)

DIMENSIONS: Equatorial diameter 20 (24) 31 μ .

DISTRIBUTION: Cookson (1957) and Harris (1965a) report the species from Victorian sediments of Upper Cretaceous and Lower Tertiary age. In the present study it was found infrequently in Victorian Upper Cretaceous sediments that contain the *Nothofagidites* Microflora.

Tricolpites pannosus sp. nov.

(Pl. 8, fig. 5-8)

DIAGNOSIS: Pollen grains tricolpate, isopolar, prolate, to oblate spheroidal. Amb subcircular to convexly subtriangular. Exine 1 μ thick, nexine thicker than sexine, finely and faintly scabrate in surface view (LO pattern). Colpi with ragged margins, 5-8 μ long in polar view, 9-15 μ long in equatorial view.

DIMENSIONS: Equatorial diameter 15 (24) 30 μ ; polar diameter 19 (22) 26 μ .

HOLOTYPE: Preparation D359/2, 31.5 118.7, Y.353. Pl. 8, fig. 6. Polar aspect. Amb subcircular, diameter 19 μ ; colpi 5 μ long, with ragged margins; exine 1 μ thick, faintly scabrate.

TYPE LOCALITY: South Australia, Haddon Downs No. 5 well, 465 ft.

REMARKS AND COMPARISON: *Tricolpites pannosus* sp. nov. possesses a thin delicate exine that is often imperfectly preserved in sediments containing mildly carbonized organic matter. It resembles *T. fissilis* Couper 1960, but is considerably

smaller and has shorter colpi. *T. errugatus* Hedlund 1966 is smaller than *T. pannosus* and its colpi extend the full length of the grain.

The specimen figured by Evans (1966a, Pl. 1, fig. 24) as *T. fissilis* shows the characters of *T. pannosus*, and its exine is torn about the polar ends of two colpi.

DISTRIBUTION: Usually abundant in its initial appearances where it is associated with youngest occurrences of *Coptospora paradoxa* (Cookson & Dettmann) Dettmann 1963 in sediments of late Albian (or ?Cenomanian) age. The species extends into the late Upper Cretaceous but has not been recorded from Tertiary sediments.

***Tricolpites sabulosus* sp. nov.**

(Pl. 8, fig. 11-13)

DIAGNOSIS: Pollen grains isopolar, oblate, tricolpate (?tricolporate), angulo-aperturate. Amb triangular with straight to strongly concave sides. Colpi short, narrow slits, 4-7 μ long in polar view. Exine 1-1.5 μ thick, 2-layered; nexine smooth, thicker than sexine which is granulate, with coarse and fine grana uniformly distributed over entire surface.

DIMENSIONS: Equatorial diameter 26 (32) 38 μ ; polar diameter (5 specimens) 20 (21) 23 μ .

HOLOTYPE: Preparation F119/4, 34.1 118.4, GSV 61888. Pl. 8, fig. 11, 12. Polar aspect. Amb convexly triangular, diameter 30 μ ; colpi 4-5 μ long; exine 1.5 μ thick; grana 0.5-1 μ in basal diameter, regularly distributed over whole surface.

TYPE LOCALITY: Victoria, F.B.H. Flaxmans No. 1 well, 4479-96 ft (core 5).

REMARKS AND COMPARISON: Grains situated in lateral aspect suggest that the apertures are colpate rather than colporate. Comparison may be drawn with *Beaupreadites verrucosus* Cookson 1950, which differs sculpturally in possessing a finely pitted sexine that bears irregularly distributed grana and verrucac; and with *Tricolpites gillii* Cookson 1957 which is smaller than *T. sabulosus* and has much finer sculpture. The fossil pollen of *Psittacopollis* van Ameron 1965 and the grains of the living *Symplocus* (see Erdtman 1952, p. 424-5; fig. 242C) are superficially similar in morphology to *T. sabulosus* but their apertures are clearly tricolporate.

DISTRIBUTION: Sometimes common, and with restricted vertical distribution, in Otway Basin late Cretaceous sediments. It occurs only in the *Nothofagidites* Microflora.

TURMA POROSSES Naumova emend. Potonié 1960

Subturma TRIPORINES Naumova emend. Potonié 1960

Genus *Triorites* Cookson ex Couper 1953

TYPE SPECIES (by subsequent designation of Couper 1953, p. 60): *Triorites magnificus* Cookson 1950.

DISCUSSION: Potonié (1960), perhaps justifiably, restricted the genus to those forms possessing sunken apertures and clavate-baculate sculpture. Of the many species that Cookson (1950, 1957), Cookson & Pike (1954), and Couper (1953, 1960a) assigned to *Triorites*, only *T. magnificus* Cookson 1950 and *T. clavatus* Cookson 1957 conform with the Potonié emendation. The remaining species were considered by Potonié to be morphologically similar to other validly instituted genera. It is apparent from the literature however that many triorate form genera are mutually overlapping and some are insecurely founded.

As an exhaustive review of triorate forms does not fall within the scope of this paper, Couper's (1953) diagnosis of *Triorites* is followed without modification. Moreover it is now known that Mr. W. K. Harris (pers. comm.) will publish a full review of *Triorites*, and it is understood that, in this, forms described by Cookson and Pike as *T. edwardsii* are to be allocated to a new generic category.

***Triorites minor* Couper 1953**

(Pl. 8, fig. 22)

DIMENSIONS: Equatorial diameter 14 (20) 25 μ .

DISTRIBUTION: Couper (1953) described this species from New Zealand where according to his subsequent (1960a) paper it ranges from Senonian to Upper Oligocene. *Triorites minor* is widely distributed, and in places is common, in the Upper Cretaceous of the Otway Basin. Its first appearances are within the *Appendicisporites distocarinatus* Zone and it extends into sediments containing the *Nothofagidites* Microflora.

***Triorites edwardsii* Cookson & Pike 1954**

(Pl. 8, fig. 21)

1954 *Triorites edwardsii* Cookson & Pike (*pars*), p. 214-5; Pl. 2, fig. 101, 105, 106 (*non* fig. 102, 103, 104, 107).

1965 *Triorites edwardsii* Cookson & Pike 1954: Harris p. 94; Pl. 28, fig. 1. [1965a]

DIMENSIONS: Equatorial diameter 25 (33) 41 μ .

REMARKS: Forms here referred to *Triorites edwardsii* possess strongly developed thickenings about the apertures and as such appear to be morphologically distinct from certain of the specimens allocated to the species by Cookson & Pike. A full morphological and taxonomic account of the species and related Australian forms is already in preparation (W. K. Harris, pers. comm.) and thus no description is provided herein. The specimen figured by Evans (1966a, Pl. 1, fig. 18), from his *Nelsoniella aceras* Zone, is now regarded by him (pers. comm.) as distinct from species here assigned to *T. edwardsii* and to aff. *T. edwardsii*.

DISTRIBUTION: Rarely common, but of undoubted stratigraphic importance, in Victorian Upper Cretaceous and Lower Tertiary. Its first appearances are in upper horizons of Taylor's (1964) Zonule A (Senonian); and Harris (1965a) illustrated a specimen from the Pebble Point Formation (Middle Paleocene). Examples depicted by Cookson & Pike (1954, Pl. 2, fig. 101, 105, 106) are from bores at Lal Lal and from the Pebble Point Formation. Mchedlishvili & Samoilovich (1962) record, but do not describe or illustrate, *Triorites edwardsii* from the Senonian of Siberia.

aff. *Triorites edwardsii* Cookson & Pike 1954

(Pl. 8, fig. 20)

1954 *Triorites edwardsii* Cookson & Pike (*pars*), p. 104-5; Pl. 2, fig. 103, 107.

DIMENSIONS: Equatorial diameter (6 specimens) 20 (25) 29 μ .

REMARKS: Uppermost Cretaceous pollen here assigned to the above category are comparable to certain specimens referred by Cookson & Pike to their *Triorites edwardsii*. However, the form is distinct from *T. edwardsii* s. st. in being unthickened about the apertures.

DISTRIBUTION: A rare type in the Upper Cretaceous, where it is restricted to the upper part of the sequence containing the *Nothofagidites* Microflora.

Genus **Proteacidites** Cookson ex Couper 1953

TYPE SPECIES (by subsequent designation of Couper 1953, p. 42): *Proteacidites adenathoides* Cookson 1950.

Proteacidites scaboratus Couper 1960

(Pl. 8, fig. 19)

DIMENSIONS: Equatorial diameter 25 (29) 35μ .

REMARKS: The south-eastern Australian specimens appear to be identical with those described by Couper (1960a, p. 52; Pl. 5, fig. 22, 23) under the above designation, apart from their slightly smaller size. Harris (1965a, p. 92; Pl. 29, fig. 13, 14) illustrates and comments upon examples which he says have 'a thicker exine around the apertures'. The specimens figured by Evans (1966a, Pl. 1, fig. 11, 20) as *Proteacidites* sp. and *Triorites minor* Couper 1953 respectively may be representatives of *P. scaboratus* Couper.

DISTRIBUTION: Described from New Zealand where it is reported to be restricted to Upper Senonian (or Maestrichtian) and Danian sediments (Couper 1960a); and reported by Harris (1965a) from the Lower Palaeocene of Victoria. In the Otway Basin, it is fairly common in the *Tricolpites pachyexinus* Zone and in the *Nothofagidites* Microflora. Its initial appearances coincide with those of *Tricolpites pachyexinus* Couper 1953 and *Hexagonifera vermiculata* Cookson & Eisenack 1961 in Taylor's (1964) Zonule A (Senonian).

Proteacidites amolosexinus sp. nov.

(Pl. 8, fig. 15-18)

DIAGNOSIS: Pollen grains triorate, isopolar, prolate, anguloaperturate. Amb triangular with straight to weakly convex or concave sides. Ora circular, $4-6\mu$ in diameter. Exine $2-3\mu$ thick, thickening slightly about apertures, 2-layered. Nexine $1.5-2.5\mu$ thick, smooth. Sexine delicate, less than 1μ thick; sculpture finely granulate-pilate, forming a fine-meshed reticulum in surface view; lumina ca. 1μ in diameter, slightly smaller about apertures. The delicate sexine is sometimes absent, often imperfectly preserved. In imperfectly preserved specimens, the surface sexine pattern is finely granulate or almost smooth, and a radial lineation of the grana about the apertures is sometimes discernible (Pl. 8, fig. 16).

DIMENSIONS: Equatorial diameter 40 (54) 77μ .

HOLOTYPE: Preparation F363/1, 50.1 126.6, GSV 61893. Pl. 8, fig. 17, 18. Polar aspect. Amb triangular, diameter 46μ ; ora 6μ in diameter; exine 2.5μ thick; nexine 2μ thick; sexine ca. 0.5μ thick, finely reticulate in surface view.

TYPE LOCALITY: Victoria, F.B.H. Port Campbell No. 4 well, 2892-2912 ft (core 2).

COMPARISON: The species is similar to *Proteacidites franktonensis* Couper 1960, but differs in having smaller ora and finer sculptural elements. *P. recto-marginis* Cookson 1950 has larger ora and thicker sexine.

DISTRIBUTION: Widely distributed in the Otway Basin where it occurs only in the *Nothofagidites* Microflora.

Subturma POLYPORINES Naumova emend. Potonié 1960

Genus **Nothofagidites** Erdtman ex Potonié 1960

TYPE SPECIES (by subsequent designation of Potonié 1960, p. 132): *Nothofagidites flemingii* (Couper) Potonié 1960.

DISCUSSION: From studies of extant *Nothofagus* material, Cranwell (1939, 1963, 1964), Cookson (1946), Cookson & Pike (1955), and Couper (1953, 1960a, b) have established that *Nothofagus*-pollen is widespread, often abundant, in Tertiary sediments of Australasia, Antarctica, and South America. Couper (1953, 1960a, b) and Cranwell (1963, 1964) have also confirmed that pollen of *Nothofagus* exists in Upper Cretaceous (Senonian and later) sequences of New Zealand and Antarctica.

The *Nothofagus*-like pollen described below are therefore of palaeobotanical and phytogeographic significance, for their occurrence in Senonian deposits of the Otway Basin establishes a pre-Tertiary occurrence of *Nothofagus* in south-eastern Australia.

These Victorian Upper Cretaceous pollen, assigned to *Nothofagidites senectus* sp. nov., are morphologically comparable with pollen of the *Nothofagus brassi* group (Cookson & Pike 1955). However, because of the reasons cited by Potonié (1960, p. 133) the grains are referred to the form generic category *Nothofagidites* Erdtman ex Potonié, rather than to the natural genus *Nothofagus* Blume.

***Nothofagidites senectus* sp. nov.**

(Pl. 8, fig. 23-25)

DIAGNOSIS: Pollen grains, isopolar, polyorate, oblate to peroblate. Ora comprise 4-6 (usually 5) 'colpoid' apertures with straight sides and broadly rounded ends; length of apertures $5-8\mu$ in lateral view, $2-4\mu$ in polar view; oral rims unthickened. Amb subcircular to polygonal; sides convex or (rarely) straight between ora. Exine ca. 0.75μ thick, finely spinulate; spinules ca. 0.5μ high, 0.5μ in basal diameter, spaced $0.5-1\mu$ apart over entire surface.

DIMENSIONS: Equatorial diameter 19 (23) 30μ ; polar diameter 12 (14) 16μ .

HOLOTYPE: Preparation F119/9, 36.9 114.9, GSV 61898. Pl. 8, fig. 23, 24. Polar aspect. Amb pentagonal (interoral sides convex), diameter 19μ ; exine ca. 0.75μ thick, spinulate; spinules 0.5μ in basal diameter, 0.5μ high, comprehensively and uniformly distributed; 5 ora, each $2-3\mu$ long (polar view).

TYPE LOCALITY: Victoria, F.B.H. Flaxmans No. 1 well, 4479-96 ft (core 5).

REMARKS AND COMPARISON: The specimen illustrated by Evans (1966a, Pl. 1, fig. 16) almost certainly belongs to *Nothofagidites senectus* sp. nov. The species is characterized by small grains lacking thickened rims around the apertures. These features indicate close relationship with extant grains of the *Nothofagus brassi*-type as described by Cookson & Pike (1955).

Nothofagidites senectus resembles *Nothofagus waiparensis* Couper 1960, but the exine of the latter is said to be thickened about the apertures. It is readily distinguishable from *Nothofagidites emarcidus* (Cookson) Harris 1965 in having shorter colpoid apertures and uniformly distributed spinules. *Nothofagus diminuta* Cookson 1959 has longer, more closely spaced spinules and its amb is concave between the apertures.

DISTRIBUTION: The species is widely distributed, though rarely common, in the late Cretaceous sediments of the Otway Basin containing the *Nothofagidites* Microflora. Its first appearances are within the upper part of Taylor's (1964) Zonule A (Senonian). Evans (1966a, p. 27) reports a similar first appearance within or just preceding his *Xenikoon australis* Zone.

Genus **Stephanoporopollenites** Pflug ex Pflug & Thomson 1953

TYPE SPECIES (by subsequent designation of Pflug & Thomson in Thomson & Pflug 1953, p. 90): *Stephanoporopollenites hexaradiatus* (Thiergart) Pflug & Thomson 1953.

Stephanoporopollenites obscurus Harris 1965

(Pl. 8, fig. 26-28)

DIMENSIONS: Equatorial diameter 27 (31) 38 μ ; polar diameter (3 specimens) 20, 27, 28 μ .

DISTRIBUTION: Rarely common, but occurs in the majority of Upper Cretaceous samples examined from the Otway Basin. Harris (1965a) described the form from Victorian Lower Tertiary strata.

Acknowledgements

Grateful acknowledgement is made to the following institutions for provision of material that forms the basis of this work: Geological Survey of Victoria, Geological Survey of Queensland, Department of Mines of South Australia, Frome-Broken Hill Company Pty. Ltd., Haematite Petroleum Proprietary Ltd., and Esso Standard Oil (Australia) Ltd. Special thanks are extended to Dr P. R. Evans (Bureau of Mineral Resources), Mr B. E. Balme (University of Western Australia), Dr I. C. Cookson (University of Melbourne), Mr W. K. Harris (Department of Mines, South Australia), for the helpful advice they freely gave during the course of this study. The Director, Bureau of Mineral Resources, has kindly granted permission for us to quote from unpublished records by Dr Evans.

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Explanation of Plates

PLATE 6

All figures $\times 500$ unless otherwise specified; from unretouched negatives

Fig. 1, 2—*Stereisporites viriosus* sp. nov. Holotype; proximal and distal foci.

Fig. 3-5—*Cicatricosisporites cuneiformis* Pocock 1965. Preparation B266/4, 33.3 118.6.

- Y.352; Qld. Mines Dept. bore Styx N.S.24, 471 ft 3, 4, Proximal and distal foci, 5, Portion of distal exine ($\times 1000$).
- Fig. 6-8—*Clavifera triplex* (Bolkhovitina) Bolkhovitina 1966. 6, 7, Proximal and distal foci; preparation F336/1, 28.8 125.4, GSV 61864; Mines Dept. Vic. Mepunga No. 7 bore, 3413-28 ft 8, Median focus; preparation F237/14, 30.9 117.7, GSV 61865; Mines Dept. Vic. Timboon No. 5 bore, 3286-97 ft.
- Fig. 9-12—*Ornamentifera sentosa* sp. nov. 9, 10, Proximal and distal foci; preparation F368/11, 38.4 122.1, GSV 61866; F.B.H. Port Campbell No. 4 well, 3821-38 ft. 11, 12, Holotype, proximal and median foci.
- Fig. 13-20—*Appendicisporites distocarinus* sp. nov. F.B.H. Fergusons Hill No. 1 well, 2427-37 ft 13, Proximal focus, preparation F270/9, 35.5 107.6, GSV 61868. 14, Distal focus, preparation F270/4, 33.5 117.6, GSV 61869. 15, Portion of distal exine ($\times 1000$), preparation F270/13, 35.5 119.4, GSV 61870. 16-18, Holotype; Proximal and distal foci, and distal sculptural detail ($\times 1000$), respectively. 19, 20 ($\times 1000$), lateral aspect; preparation F270/8, 33.9 120.6, GSV 61872.

PLATE 7

All figures $\times 500$; from unretouched negatives

- Fig. 1-3—*Camarozonosporites amplus* (Stanley) comb. nov. 1, 2, Proximal and distal foci; preparation F338/2, 28.3 118.7, GSV 61873; Mines Dept. Vic. Mepunga No. 7 bore, 3017-25 ft. 3, Median focus; preparation F240/6, 26.4 121.5, GSV 61874; Mines Dept. Vic. Timboon No. 5 bore, 2949-63 ft.
- Fig. 4, 5—*Camarozonosporites bullatus* Harris 1965. Proximal and distal foci; preparation F317/3, 40.8 120.5, GSV 61875; Mines Dept. Vic. Wangoom No. 6 bore, 3065-72 ft.
- Fig. 6, 7—*Camarozonosporites ohaiensis* (Couper) comb. nov. Mines Dept. Vic. Timboon No. 5 bore, 2949-63 ft. 6, Proximal focus; preparation F240/13, 31.9 115.8, GSV 61876. 7, Median focus; preparation F240/7, 34.7 114.7, GSV 61877.
- Fig. 8-12—*Kraeuselisporites jubatus* sp. nov. 8, 9, Proximal and distal foci; preparation F235/5, 35.9 120.8, GSV 61878; Mines Dept. Vic. Timboon No. 5 bore, 3500-04 ft. 10, 11, Holotype; proximal and distal foci. 12, Lateral aspect; preparation F301/2, 48.1 124.2, GSV 61880; Mines Dept. Vic. Wangoom No. 2 bore, 3968-72 ft.
- Fig. 13—*Aequitriradites hispidus* sp. nov. Holotype; distal focus.

PLATE 8

All figures $\times 750$ unless otherwise specified; from unretouched negatives

- Fig. 1—*Balmesporites glenelgensis* Cookson & Dettmann 1958. Median focus ($\times 125$); preparation F240/8, 34.1 110.1, GSV 61881; Mines Dept. Vic. Timboon No. 5 bore, 2949-63 ft.
- Fig. 2—*Laevigatosporites major* (Cookson) Krutzsch 1959. Lateral aspect ($\times 500$); preparation F338/9, 30.6 122.2, GSV 61882; Mines Dept. Vic. Mepunga No. 7 bore, 3017-25 ft.
- Fig. 3—*Dacrydiumites florinii* Cookson & Pike 1953. Distal focus; preparation F316/1, 37.9 116.7, GSV 61883; Mines Dept. Vic. Wangoom No. 2 bore, 2834-39 ft.
- Fig. 4—*Phyllocladites mawsonii* Cookson 1947. Distal focus; preparation F119/8, 40.2 110.6, GSV 61884; F.B.H. Flaxmans No. 1 well, 4479-96 ft.
- Fig. 5-8—*Tricolpites pannosus* sp. nov. 5, Polar view; preparation F235/1, 55.9 122.0 GSV 61885; Mines Dept. Vic. Timboon No. 5 bore, 3500-04 ft. 6, Holotype; polar view. 7, polar view, preparation D359/1, 45.8 119.2, Y.354; South Australia, Haddon Downs No. 5 bore, 465 ft. 8, Lateral aspect; preparation D359/2, 30.8 123.6, Y.355; loc. as fig. 7.
- Fig. 9, 10—*Tricolpites pachyexinus* Couper 1953. 9, Polar view; preparation F367/7, 39.4 121.0, GSV 61886; F.B.H. Port Campbell No. 4 well, 3519-36 ft. 10, Oblique aspect; preparation F103/1, 36.6 118.8, GSV 61887; F.B.H. Port Campbell No. 1 well, 4862-69 ft.
- Fig. 11-13—*Tricolpites sabulosus* sp. nov. 11, 12, Holotype; surface view and optical section of exine. 13, Polar view, preparation F119/3, 31.4 111.7, GSV 61889; loc. as fig. 4.

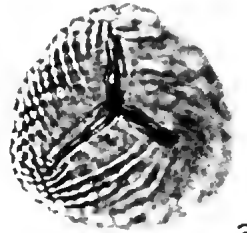
- Fig. 14—*Tricolpites gillii* Cookson 1957. Polar view; preparation F119/7, 42·2 119·5, GSV 61890; loc. as fig. 4.
- Fig. 15-18—*Proteacidites amolosexinus* sp. nov. Polar views (all $\times 500$). 15, Preparation F108/2, 42·1 125·5, GSV 61891; F.B.H. Port Campbell No. 1 well, 3997-4009 ft. 16, Corroded specimen having imperfectly preserved sexine; preparation F367/11, 35·5 117·3, GSV 61892; loc. as fig. 9. 17, 18, Holotype.
- Fig. 19—*Proteacidites scaboratus* Couper 1960. Polar view; preparation F367/10, 39·9 120·5, GSV 61894; loc. as fig. 9.
- Fig. 20—Aff. *Triorites edwardsii* Cookson & Pike 1954. Polar view; preparation F363/1, 51·0 115·8, GSV 61895; F.B.H. Port Campbell No. 4 well, 2892-2912 ft.
- Fig. 21—*Triorites edwardsii* Cookson & Pike 1954 *pars*. Polar view; preparation F118b/3, 35·1 121·3, GSV 61896; F.B.H. Flaxmans No. 1 well, 4309-16 ft.
- Fig. 22—*Triorites minor* Couper 1953. Polar view; preparation F129/2, 43·9 120·9, GSV 61897; F.B.H. Flaxmans No. 1 well, 5543-46 ft.
- Fig. 23-25—*Nothofagidites senectus* sp. nov. Polar views. 23, 24, Holotype. 25, Six-pored example; preparation F119/6, 28·8 126·0, GSV 61899; loc. as fig. 4.
- Fig. 26-28—*Stephanoporopollenites obscurus* Harris 1965. 26, 27, High focus and optical section of oblique polar view; preparation F036/4, 50·6 120·0, GSV 61900; F.B.H. Eumeralla No. 1 well, 2835-49 ft. 28, Lateral aspect; preparation F401/1, 39·1 108·9, GSV 61901; Mines Dept. Vic. Latrobe No. 1 bore, 1627-31 ft.



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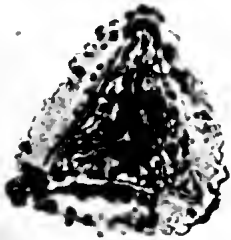
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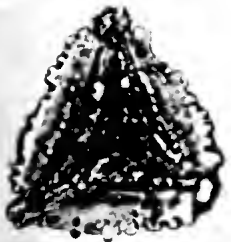
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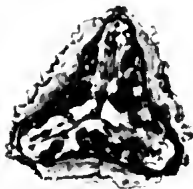
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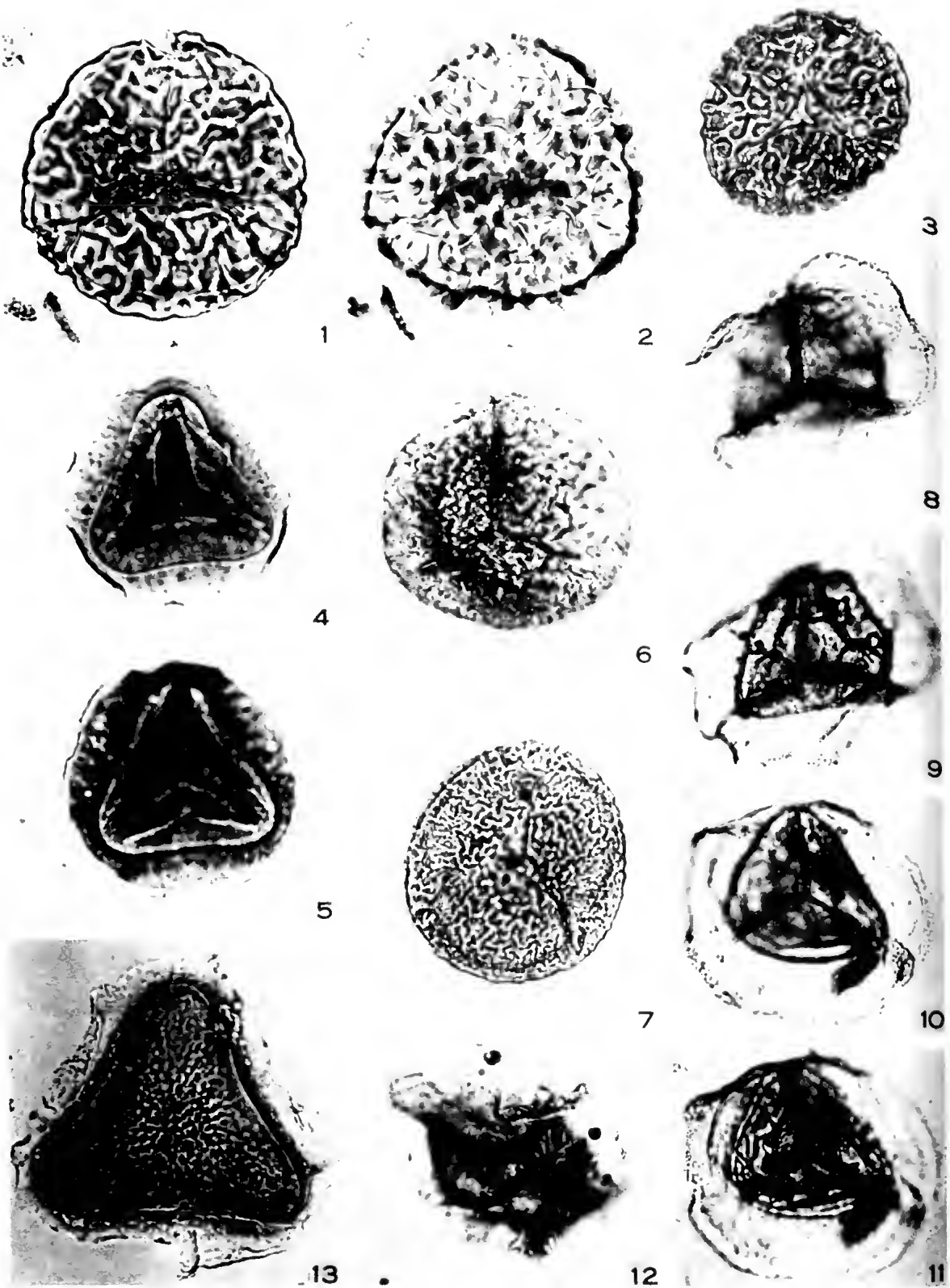
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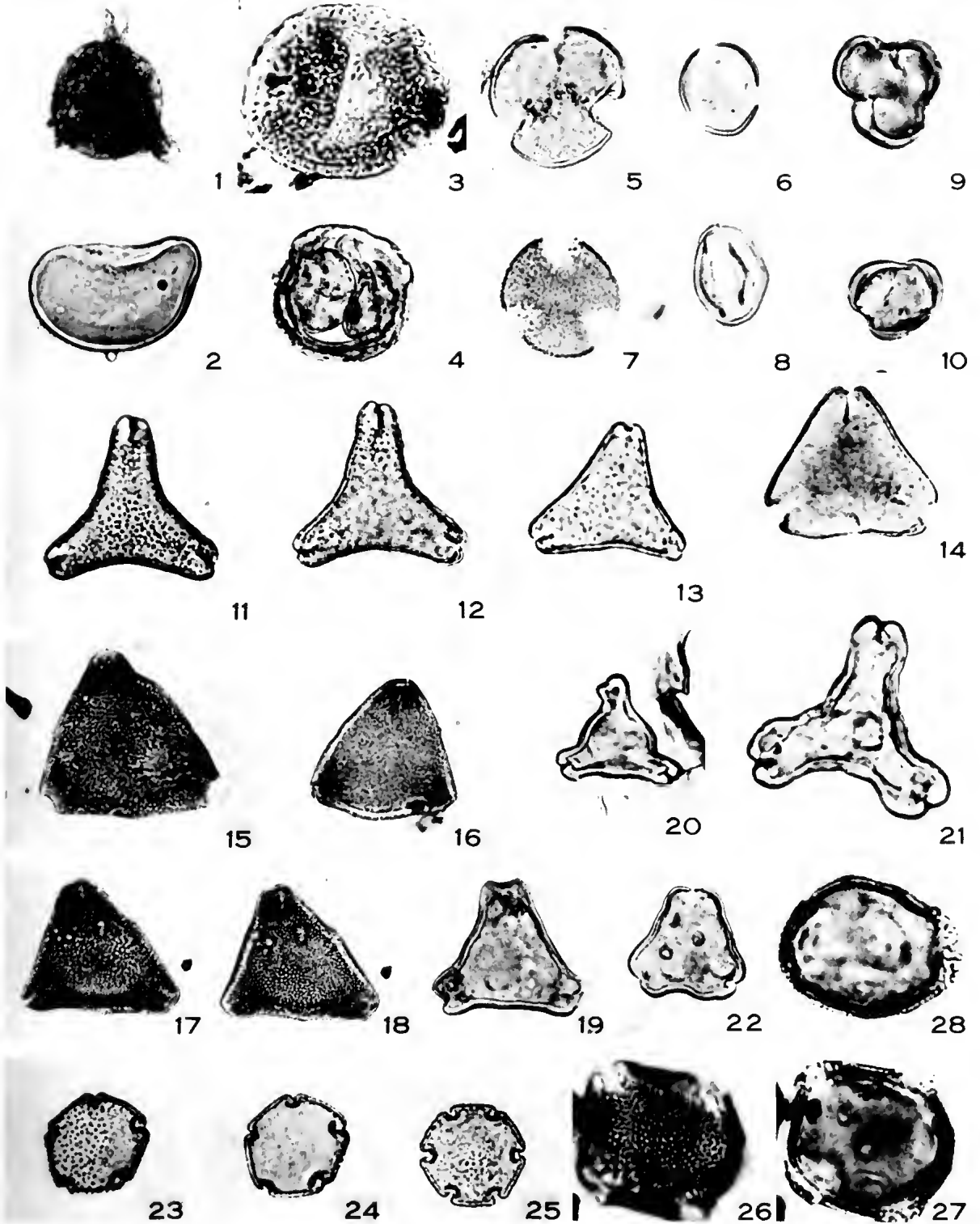


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TERTIARY FISH FROM MORWELL, VICTORIA

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This note records the discovery (by P.L.H.) of fossil fish in a late Tertiary deposit occupying an erosion hollow in the surface of the probably Miocene brown coal of the Morwell 1^A coal seam (Fig. 1). The find is particularly

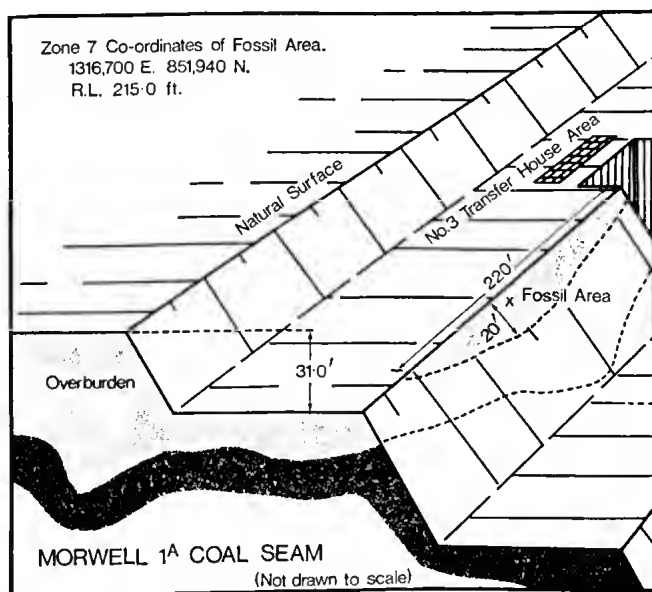


Fig. 1—Schematic diagram of clays occupying a hollow in the Morwell 1^A coal seam.

interesting since Hills (1958, p. 100) stated: 'A notable feature is the complete absence of vertebrates from the brown-coals and associated clays of Victoria. . . .' The beds consist of an upper layer of dark grey, or black, lignitic clay which has yielded the fish, and a lower layer of buff, laminated clay which contains immense numbers of ostracodes of the genus *Mytilocypris*. The ligneous clays which contain the fish also contain innumerable diatoms of the genus *Campylodiscus*, sponge spicules, pollen grains, and a great deal of black, organic material. The clays occur within a large depression which has resulted from a fire in the coal surface. This and other similar depressions in the Morwell Open

Cut have been described and illustrated by Gloc (1960, p. 91). Tindale (pers. comm.) is of the opinion that the sediments were laid down in a brackish environment.

Two fish have been discovered, National Museum of Victoria numbers P.26606 and P.26061a, b, and both of these consist of dissociated fragments. It is possible neither to determine their affinities in any detail, nor to state whether they belong to the same taxa. P.26060 consists of a sinuous string 8 mm long of twelve vertebral impressions which bear fine haemal and neural spines. Toward the posterior part of the chain are the dorsal fin and opposed to it fragments of another fin. Neither of these is completely preserved, but a few radials of the dorsal fin are visible, as are some of the lepidotrichia of both fins. P.26061a, b, consists of dissociated ribs, scales, and part of an element tentatively identified as a cleithrum. This represents a larger fish than P.26060. The ribs are well curved and measure about 10 mm in a straight line between extremities. The scales are ctenoid with well defined circuli, about 10-12 strong radii, and numerous, small, marginal spines in the apical region. Only the ventral portion of the supposed cleithrum is present. Very little bone is left in any of the elements; however, occasional fragments are preserved and they present a charcoal-like appearance. It is possible that fin fragments are present but in a very broken and distorted state. The remains of P.26061a, b, are scattered over at least 50 sq. cms. The fish are both typically teleostean in type, and the scales of P.26061a, b, are possibly those of a perciform acanthopterygian. More complete material is necessary to resolve the problem. The authors wish to thank Dr. K. G. McKenzie for identifying the ostracodes, Mr. B. Tindale for identifying the diatoms, and Miss D. B. Wade for drafting the diagram.

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STRUCTURAL GEOLOGY AND GRAPTOLITES OF THE ORDOVICIAN ROCKS AT STEIGLITZ, VICTORIA, AUSTRALIA

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* Geology Department, University of Melbourne, Victoria.

Abstract

Mesoscopic and macroscopic structures in the Ordovician sediments of the Steiglitz district have been mapped, described, and analysed. Three major macroscopic folds are recognized—the Moorabool Synclinorium, the Steiglitz Anticlinorium and the Anakie Synclinorium. In the north-eastern section, monoformal warping of the folded sediments occurs about steeply plunging axes. Two large faults, the Hanover and Rowsley, are described. Faunal analysis is given of graptolites occurring in the area, with description of one new species.

Introduction

The Steiglitz district is located about 20 miles NW. of Geelong. Ordovician sediments are exposed in the valleys of the Moorabool R., Sutherlands Ck and their tributaries where erosion has removed the Cainozoic sediments and volcanics which overlie the Ordovician rocks with strong angular unconformity. Although deeply weathered and often poorly exposed, the Ordovician sandstones and slates outcrop more or less continuously along the main streams.

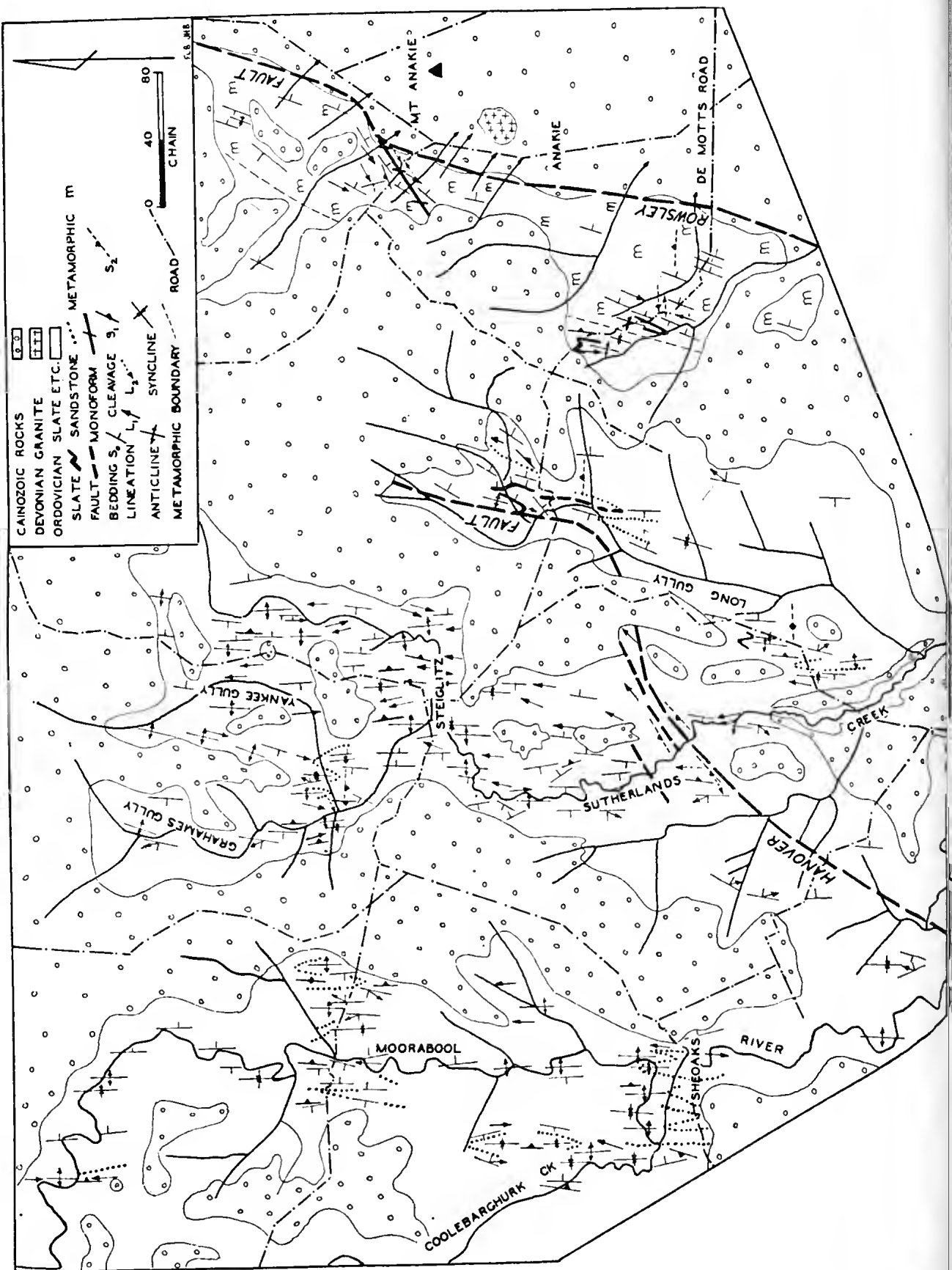
East of the Rowsley escarpment, granites are exposed as inliers in the Cainozoic basalts. The granitic rocks post-date the Ordovician sediments on which they have imposed a thermal metamorphism, the effects of which are apparent for a distance of about 1 mile W. from the escarpment.

In 1909, W. H. Ferguson mapped a narrow strip of terrain running north-south through Steiglitz township. This map was published in 1940. Some of the graptolites collected by Ferguson were identified by T. S. Hall who published lists of recognized forms (1913). W. J. Harris and D. E. Thomas (1949) described the broad aspects of the geology of the Meredith district, which included the Steiglitz area.

Mesoscopic Structures

The Ordovician sediments consist of shales, slates, siltstones and greywacke-type sandstones, with rare, thick orthoquartzites. Along the eastern margin of the area, the sediments, which had undergone very low-grade regional metamorphism during folding, have been thermally metamorphosed to spotted and andalusite slates, hornfels and metagreywackes. In the pre-Darriwilian beds sandstones are prominent in the lithology, but the Darriwilian beds are almost exclusively shale and slates, with only rare greywackes and quartzites. The lithology has exerted a marked influence on the style of the mesoscopic structures and on the geometry of the individual folds.

Throughout the sequence, simple and oscillatory graded bedding, convoluted bedding and current bedding are frequent, indicative of deposition of the sediments by turbidity currents. The beds have been tightly folded into asymmetric similar-style anticlines and synclines, with axial surfaces dipping steeply E., and



axes plunging gently to the N. and S. Axial plane cleavages have been imposed on all the folded rocks, while slates and siltstones are strongly lineated.

(i) FOLDING

The closeness and tightness of the mesoscopic folds are variable; hinge lines may be spaced at intervals of from 5 ft to 600 ft. Normally, the fold hinges are sharp, but not angular. However, quite angular hinges occur in folded slate beds (Fig. 2) and in a folded sequence of sandstones they may be relatively open and rounded (Pl. 9, fig. 1). Rock type has controlled the form of the fold hinges. Fold axes plunge at angles usually less than 20° to the N. and to the S., and frequent change of plunge direction occurs throughout the area. The limbs of the mesoscopic folds dip steeply to the E. and W.; the westerly dipping limb is almost invariably steeper than the E. dipping limb, and consequently the folds are asymmetric with westerly vergence. Strike of limbs varies between $N25^\circ E$ and $N25^\circ W$, and hinge lines trend a few degrees E. of N.

Several significant departures from these average attitudes were noted. One of these occurs in a narrow belt along the Hanover Fault and another in the NE. of the mapped area, near the flexure in the Rowsley Fault. In the Mariner's Gully area, adjacent to the Hanover Fault, mesoscopic fold hinges trend NE. to ENE., sub-parallel to the fault. This variation in trend, which is more pronounced N. of the fault than to the S., is regarded as a drag effect. In this belt also, fold hinges and lineations have plunges 10° - 15° (and in isolated cases up to 50°) steeper than the regional average. Near the flexure in the Rowsley Fault, the mesoscopic structures have a complex geometry, and discussion of this area is deferred until later in this paper.

Throughout the area, even where relatively thick sandstones are involved, the style of the mesoscopic folds is 'similar'. Beds show thickening on hinges and thinning of limbs (Fig. 2), the effect being more pronounced in slates than in siltstones and sandstones. In many cases, the mesoscopic folds appear to be cylindrical, but there are a number of exposures in which the non-cylindrical geometry of the folds is obvious.

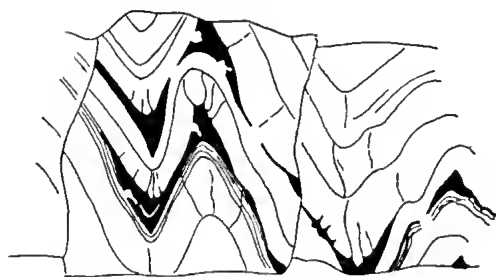


FIG. 2.—Section in cliff near junction of Yankee Gully and Sutherland Ck.
Length of section 25 ft.

(ii) CLEAVAGES

Axial-plane slaty cleavage is perfectly developed in the slates; this cleavage has a more or less uniform easterly dip of 60° to 80° , but vertical-dipping slaty cleavage was noted locally on the Moorabool R., and west-dipping cleavage was recorded near the junction of Grahame's and Yankee Gullies. This east-dipping cleavage

is a reflection of the westerly vergence of the folds. In the thicker slate beds, slaty cleavage is the dominant planar structure, completely obscuring bedding laminations. Although slaty cleavage is only weakly developed in, or absent from, the siltstones, these are broken, especially in the hinge zones of folds, by a cleavage with which is associated intense puckering of the bedding laminations. This cleavage, which has been referred to as strain-slip cleavage (Beavis 1965) is not a superposed structure. It was imposed at the same time as the slaty cleavage and represents the response of the siltstones to the folding stresses. The cleavage domains in the siltstones constitute the axial surfaces of the small folds or 'puckers' with which they are associated, and are statistically parallel to the axial surfaces of the larger mesoscopic folds in whose hinge zones the cleavage was formed.

The sandstones, too, are cleaved only in the hinge zones of mesoscopic folds. The only cleavage developed is 'fissuring' radially arranged about the axial surfaces of the folds, and statistically parallel to these surfaces: some particularly fine examples were noted at Sheoaks and at Grahame's Gully. Occasionally the fissuring forms conjugate sets, when it is finer than normal, and much more closely spaced.

There are several well defined zones, as well as some apparently isolated localities, where superposed crenulation cleavages, post-dating the main folding, have been recorded in slates, siltstones and hornfels. Superposed crenulation cleavage in this region was first observed at Ingliston in the contact aureole about the Ingliston granodiorite, where it was vertical, with E.-W. strike.

Near the Hanover Fault, in the Mariner's Gully area, the crenulation cleavage is parallel to the fault, with steep northerly dip (Pl. 10, fig. 1). In general, it is believed that the crenulation cleavage has been imposed by stresses associated with the intrusion of batholiths and with fault movement. The unique style of the cleavage (a true fracture cleavage) and its discordant geometry, indicate that it is unrelated to the main folding.

A fine crenulation cleavage was noted in Long Gully at two separate localities. In the more southerly, the cleavage forms the axial planes of small chevron folds in slates. At the more northerly occurrence, immediately S. of the Anakie-Steiglitz road, the cleavage forms the axial surfaces of small rounded flexures in steeply dipping slates. Both sets of folds have near vertical plunge, and are developed only over a very small area—less than 10 square ft. We would tend to interpret these occurrences, obviously unrelated to any major structure, as localized developments of discordant stress fields late in the folding of the sediments.

(iii) LINEAR STRUCTURES

The slates are strongly lineated, with lineations parallel to axes of the mesoscopic folds, or of segments of these folds. The two styles of lineation in the slates are microcrenulations in bedding planes due to the intersection of these by slaty cleavage, and colour layers in slaty cleavage planes, representing the trace of bedding laminae on the cleavage. The main linear structures in the siltstones are the hinge lines of the small puckers: these are restricted to the mesoscopic fold hinge zones. Elsewhere the siltstones show little or no linear structure.

Normally, the sandstones have no linear structures, but two styles occur in fold hinge zones: lozenges (Pl. 9, fig. 2) and mullions, due to the intersection of bedding by, respectively, conjugate and single sets of fissuring. On the Anakie-

Ballan Road, in the north-eastern sector, small fold mullions have been perfectly formed in a sandy siltstone, thermally metamorphosed to andalusite hornfels.

Superposed lineations, L2, are represented by fine cracks due to intersection of bedding and slaty cleavage by the crenulation cleavage S2. (Pl. 10, fig. 1). More typical L2 styles are fine crenulations in slates (Pl. 10, fig. 2-4).

Except where they occur on the hinges of mesoscopic folds, the superposed lineations have very steep plunge. In certain areas, for example on the Anakie Monoform, it was essential to distinguish between L2 and steeply plunging L1. The basis for distinction was the association of the lineation with S1 and S2, both of which were readily recognizable and distinguishable.

(iv) GEOMETRIC ANALYSIS OF MESOSCOPIC STRUCTURE

The geometric analysis of mesoscopic structural elements is shown on Fig. 3 & 4. Poles to the bedding, So, lie in a girdle with pole β , suggesting monoclinic symmetry and cylindrical folding. This is at variance with field observations, and, when other structural elements are considered (Fig. 3b, 3c) it is clear that the folding is non-cylindrical with triclinic symmetry.

The dominance of east-dipping cleavage, and of west-dipping bedding, is clearly shown on the diagrams, while the spread of B lineations (Fig. 3b) reflects not only some abnormally steep plunges, but also the overall non-cylindrical geometry of the folds.

The non-cylindrical triclinic geometry of the folded Ordovician rocks in this area is comparable to that of other areas of Ordovician rocks in Victoria where triclinic $B \perp B'$ geometry is characteristic. This geometry has been interpreted (Beavis 1967) as being the result of elongation in B during folding. Stresses

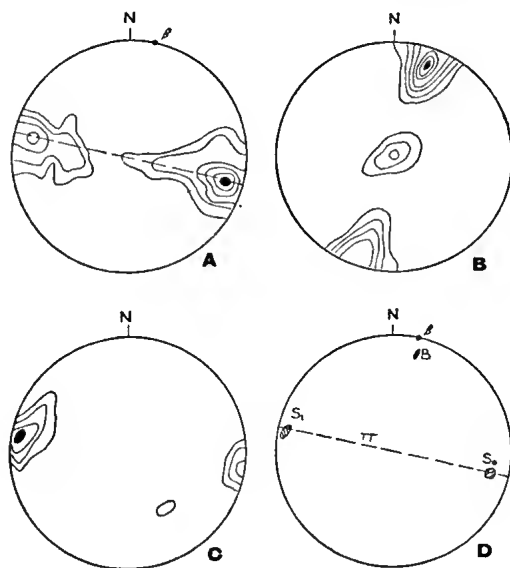


FIG. 3—Analysis of mesoscopic elements.

- a. 167πSo. Steiglitz. Contours 1, 2, 5, 10, 15, 20%
- b. 140 lineations L1, Steiglitz. Contours 1, 2, 3, 5, 10, 12, 15%
- c. 92πS1, Steiglitz. Contours 1, 2, 10, 20%
- d. Synoptic diagram.

developed normal to the compressive stresses causing the folding prevented this elongation and resulted in buckling about E.-W. axes. However, the present detailed study has shown that in the Steiglitz area, the geometry is a triclinic $B \wedge B'$ and cannot be explained by this hypothesis.

The geometry of surfaces and lineations in some selected localities of superposed structures is shown on Fig. 4. Because of the varying attitudes of the surfaces involved, there is a wide variation in the attitudes of the superposed lineation L2. Two sets of L2 occur except in some slates where L2 is represented by a single set of microcrenulations. In this latter case, the deformed L1 can be seen clearly (Pl. 2), but due to the smallness of the crenulations, measurement of the varying attitudes of L1 was not possible.

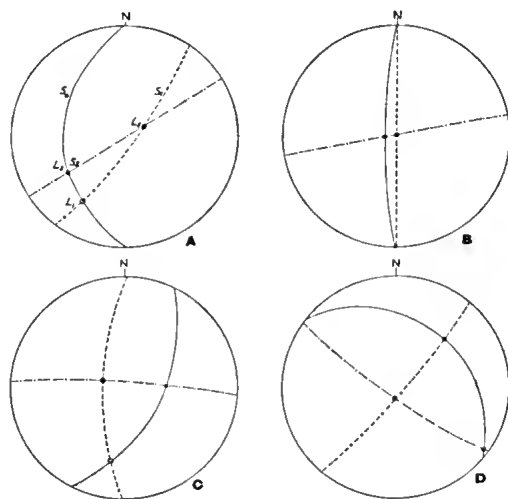


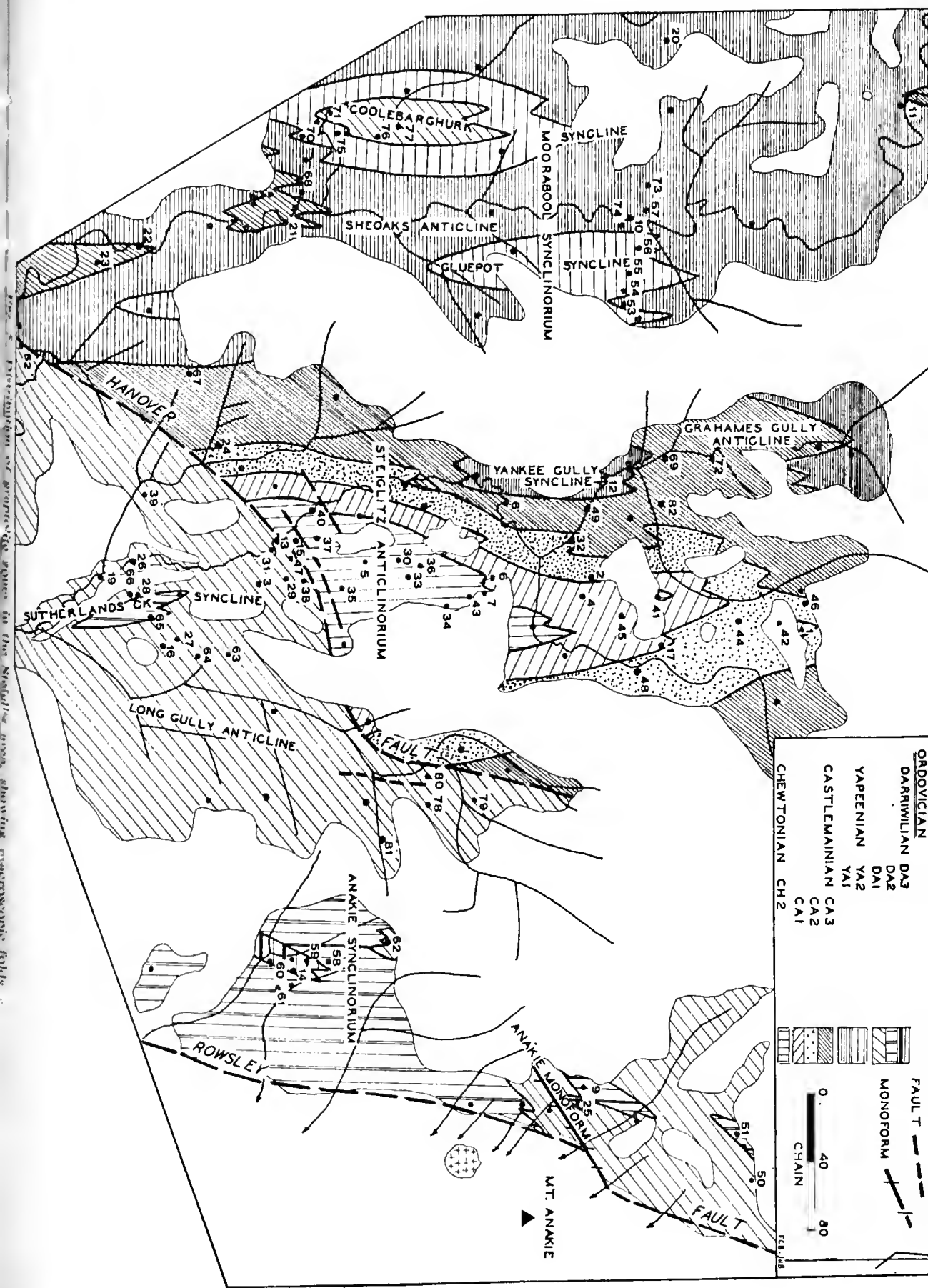
FIG. 4—Geometry of Superposed Structures.

- a. Rowsley escarpment, Stony Ck, Anakie.
- b. Junction of Yankee Gully and Sutherland's Ck.
- c. Rowsley escarpment, de Motts Road, Anakie.
- d. Sutherland's Ck, Mariner's Gully area.

Macroscopic Structure

(i) FOLDING

The form of the macroscopic folds, and the location of their hinge lines was determined from the distribution of graptolite zones and from macroscopic data. In some cases, when prominent thick sandstone or slate beds could be traced in the field, lithological mapping could be used (Fig. 1). Graptolite zones were the main criterion, however, and since fossil localities are by no means uniformly distributed, the reliability of the mapping varied. Moreover, the Ordovician sediments are obscured in some critical areas by the cover of Cainozoic rocks. As a result of these factors, our interpretation of macrostructure, shown on Fig. 5, is only one of several possible. The reliability of our interpretation can be assessed from the frequency of graptolite localities, all of which are shown on Fig. 5. The forms collected from the most representative localities (numbered on Fig. 5) are listed in Table 1.



The sequence of Ordovician zones in the area studied ranges from Chewtonian (Ch2), the base of which is not exposed, through to Darriwilian (Da3). On the basis of detailed sections between Steiglitz and Meredith the thickness of the sequence in this area is of the order of 5000 ft. In spite of careful search, no evidence of the zone of *Didymograptus* cf. *balticus* (Ch3) was obtained, and it has been inferred that this zone is absent from the Steiglitz area, although it is known at Morrisons to the NW.

(a) **The Moorabool Synclinorium:** The lowest zone exposed in this fold complex is Castlemainian (Ca3) and the highest Darriwilian (Da1). The synclinorium consists of a number of small folds, which, because of plunge reversal, tend to be impersistent, with an irregular *en echelon* pattern.

Where plunge reversal is frequent, small folds (e.g. the Sheoaks Anticline) tend to break up into still smaller folds. The Synclinorium is a basin type structure with regional plunge reversal occurring on well defined SW.-NE. axes (Fig. 6).

The hinge line of the Synclinorium is not simple, and we regard the structure as consisting of two more or less equally developed synclinals separated by the Sheoaks Anticline. On the more westerly of the two synclinal hinge lines Da1 is exposed, and on the more easterly Ya2. The great breadth of outcrop of Ya1 beds in the Moorabool Synclinorium is due to repetition on very closely spaced mesoscopic folds.

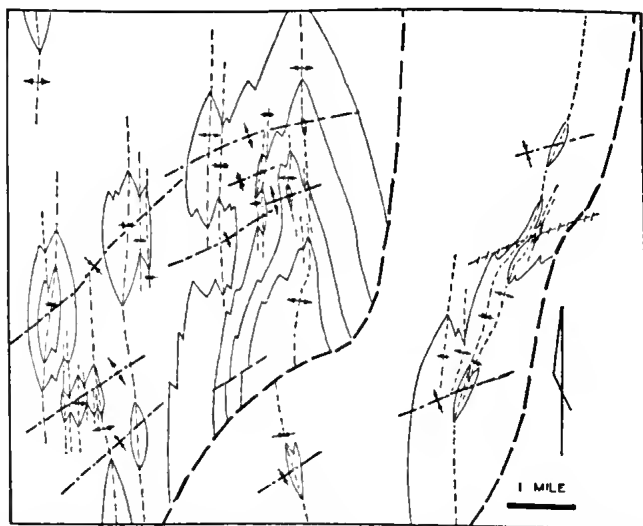


FIG. 6—Macroscopic structure of the Steiglitz area showing interpretation of macro-structure beneath Cainozoic cover, and B' axes of plunge reversal.

(b) **The Steiglitz Anticlinorium:** The centrally situated Steiglitz Anticlinorium is the most prominent of the macrofolds, and is also the least complex of these. It is a relatively broad structure, with a gentle northerly plunge, terminated on the S. and E. by the Hanover Fault. The hinge line has a general NS. trend, but in the S. shows a slight swing to the SW. as the Hanover Fault is approached. To

the N. of Steiglitz, near Durdidiwarrh, the hinge line becomes ill defined as the main anticlinorium tends to break up into smaller folds. Again, this behaviour is associated with well defined axes of plunge reversal. In the NW. sector of the western limb there is a loss of simplicity of the Anticlinorium, where, associated with reversal of plunge, the relatively large Grahame's Gully Anticline and the Yankee Gully Syncline have developed.

The greater outcrop width of the zones on the eastern limb of the Anticlinorium compared with that on the W., is a reflection of the greater steepness of the west dipping limbs noted for the mesoscopic folds. Because of the cover of Cainozoic sediments, little is known of the eastern limb of the Steiglitz Anticlinorium, and it is probable that our interpretation of this limb, shown on Fig. 6, is an oversimplification.

(c) **The Anakie Synclinorium:** Only Darriwilian beds are involved in this structure which is confined between the Rowsley and Hanover Faults, the latter separating it from the Steiglitz Anticlinorium. Because of the Cainozoic cover, little is known of this fold. There is a regional change of plunge in the de Motts Road area while a certain degree of complexity has been introduced by post-folding deformation on the Anakie Monoform. To the N., the main fold appears to be breaking up as a result of plunge reversal, and it is probable that the whole structure is more complex than we have been able to determine. The Sutherland's Creek Syncline W. from this fold may be a major structure, but we have not been able to obtain much data regarding it, nor of the anticline between this fold and the main Anakie Synclinorium. The hinge line of the Synclinorium differs slightly from that of the other macrofolds: it is remarkably sinuous, and has a general trend somewhat E. of N., rather than due N. like the Steiglitz Anticlinorium and the Moorabool Synclinorium.

(d) **The Anakie Monoform:** The term 'monoform' is used to describe this single-limbed fold structure, with steeply plunging axis, rather than the term *monoeline*, which implies a flat, or very gently plunging axis. Anomalous attitudes of bedding, cleavages, fold axes and lineation, as well as overprinted cleavage, occur in a well defined belt associated with the flexure in the Rowsley Escarpment. Two hypotheses were considered: (i) that this belt represented drag effects, associated with an easterly extension of the Hanover Fault; or (ii) the flexure marked the dying out to the E. of the Hanover Fault. Both were rejected in the subsequent mapping of the Hanover Fault trending northerly in Long Gully. No evidence was found of rupture of the beds in this zone, and movement on the flexure was insignificant in comparison with displacement on the Hanover Fault. There may be some genetic relationship between the Anakie Monoform and the Hanover Fault, but because of the Cainozoic cover in this critical area, we have not been able to establish even a field relationship between the two structures.

Evidence of the Anakie Monoform, which has warped not only folded Ordovician sediments, but also the Rowsley Fault, is shown on Fig. 7. The area is in the zone of contact metamorphism, and the rocks involved are spotted slates, andalusite hornfels and spotted greywacke. Metamorphism is relatively high grade, but fossils preserved in dense black carbonaceous slates have not been destroyed. North of Stony Creek, beds have a N.-S. strike with steep dips E. and W., and fold axes (lineations) plunge 7°-12°N. Slaty cleavage dips E. at 70°. In the lower part of Stony Creek, bedding and cleavage show a marked swing to WSW.-ENE. with almost E.-W. lineations, and between the creek and the Anakie-Ballan Road, steepen to as much as 78° to the SW. and W. In cutting No. 2 there is a localized overturning

with a reversed plunge 80° NE. on the hinge of a synform.

Between the Anakie-Ballan Road and the Cainozoic-capped ridge immediately S. from the road, bedding and cleavage have a more northerly (NE.-SW.) trend, and, in the gully S. of this ridge, strikes of bedding and slaty cleavage are once again N.-S. with plunges of lineations gently (10°) N.

An almost NE.-SW. vertical crenulation cleavage has been imposed on the rocks in the more highly deformed sections of the Monoform, such as cutting No. 2 and in the lower part of Stony Creek (Fig. 4a). On the basis of the mesoscopic data, it is inferred that the axis of the Anakie Monoform plunges steeply (60° - 80°) to the W. The Monoform clearly post-dates the main folding and the initial movement on the Rowsley Fault. However, that the beds folded rather than faulted in response to the deforming stresses suggests high confining pressures and hence relatively deep burial during deformation.

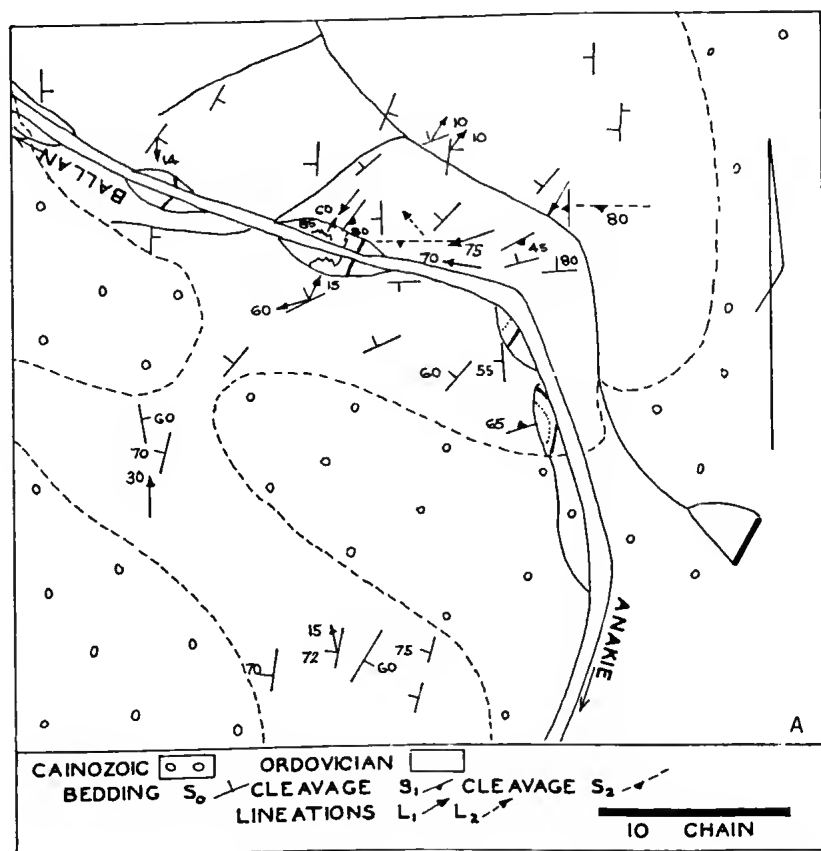


FIG. 7—The Anakie Monoform. Mesoscopic structural elements on the Monoform.

(ii) GEOMETRIC ANALYSIS OF MACROFOLDS

As noted previously, plunge reversal in the macroscopic folds occurs along reasonably well defined NE.-SW. axes (Fig. 6). These B' axes, like the main B

axes of the folds, tend to be discontinuous with a tendency to an *en echelon* pattern. The effect of plunge reversal on B' axes has been to impart a triclinic B \wedge B' symmetry to the folded mass: a fact not suggested by the π diagrams. This triclinic B \wedge B' geometry does not imply separate unrelated deformation on B and B', but rather buckling about B' synchronously with folding about B. The non-coincidence of B and β which emerged from the geometrical analysis of bedding and lineation (Fig. 3) is of interest.

The plunge of the individual mesoscopic folds is some 10°-15° steeper than that of the regional system. Such a feature is characteristic of *en echelon* folding (Campbell 1959) and implies the activity of shear couples in the folding: a view supported by the triclinic B \wedge B' geometry.

(iii) FAULTING

In the area mapped two major faults occur, both of which had been recognized by earlier workers. During the present work, these faults were studied in some detail, and we were able to show the Hanover Fault extending westerly to Long Gully, and thence northerly. Several minor faults were also recorded.

(a) **The Hanover Fault:** Ferguson (1940) recognized and mapped the Hanover Fault as the 'Hanover line of lode' in the Mariner's Gully area. The south-westerly extension of this structure to the Moorabool R. was subsequently established by Harris and Thomas (1949) who described it as a high angle thrust. Across the Hanover Fault there is a strong contrast in lithology: to the S. and E. slates predominate, while to the N. and W., sandstones and siltstones are the dominant rock types. This is a reflection of the stratigraphic break across the fault: to the S. and E. all of the rocks are Darriwilian, while to the N. and W. they range from Chewtonian through to low Darriwilian. The Hanover Fault lacks any physiographic expression, and it is on stratigraphic evidence alone that movement on the fault can be assessed.

Two areas in particular were suitable for detailed study of the Hanover Fault: the Mariner's Gully area (Fig. 8) and Long Gully. In the former area, there is marked drag of bedding and slaty cleavage, and of fold axes with abnormally high plunges. The fault itself is marked here by brecciation of sandstone and crushing of slates to a dense black gouge, while mineralization of the fault is reflected in scattered quartz at the surface.

The stratigraphic break across the fault in this area is considerable. Fossils in the northern block are Chewtonian (Ch2) while with one exception, the localities on the south of the fault yielded Darriwilian (Da1) fossils. The exception was locality 47 which yielded *Didymograptus protobifidus*. This locality is a mine dump almost on the fault, and we infer, with Harris and Thomas, that the fossiliferous material was mined on the N. side of the fault.

Associated with the fault and more or less parallel to it is a fracture cleavage which has deformed the bedding slightly and imposed a second lineation (Pl. 10, fig. 2).

Ferguson recorded the dip of the Hanover Lode as northerly. This was confirmed by observation in an old mine shaft where brecciated and mineralized rocks dipped 70°N., and cut across the bedding. Associated with the Hanover Fault and parallel to it are two minor faults. These are regarded as parallel shear zones which developed synchronously with the Hanover Fault.

Harris and Thomas, from their studies in this area, regarded the Hanover Fault as a high angle thrust and estimated the thickness of missing beds across

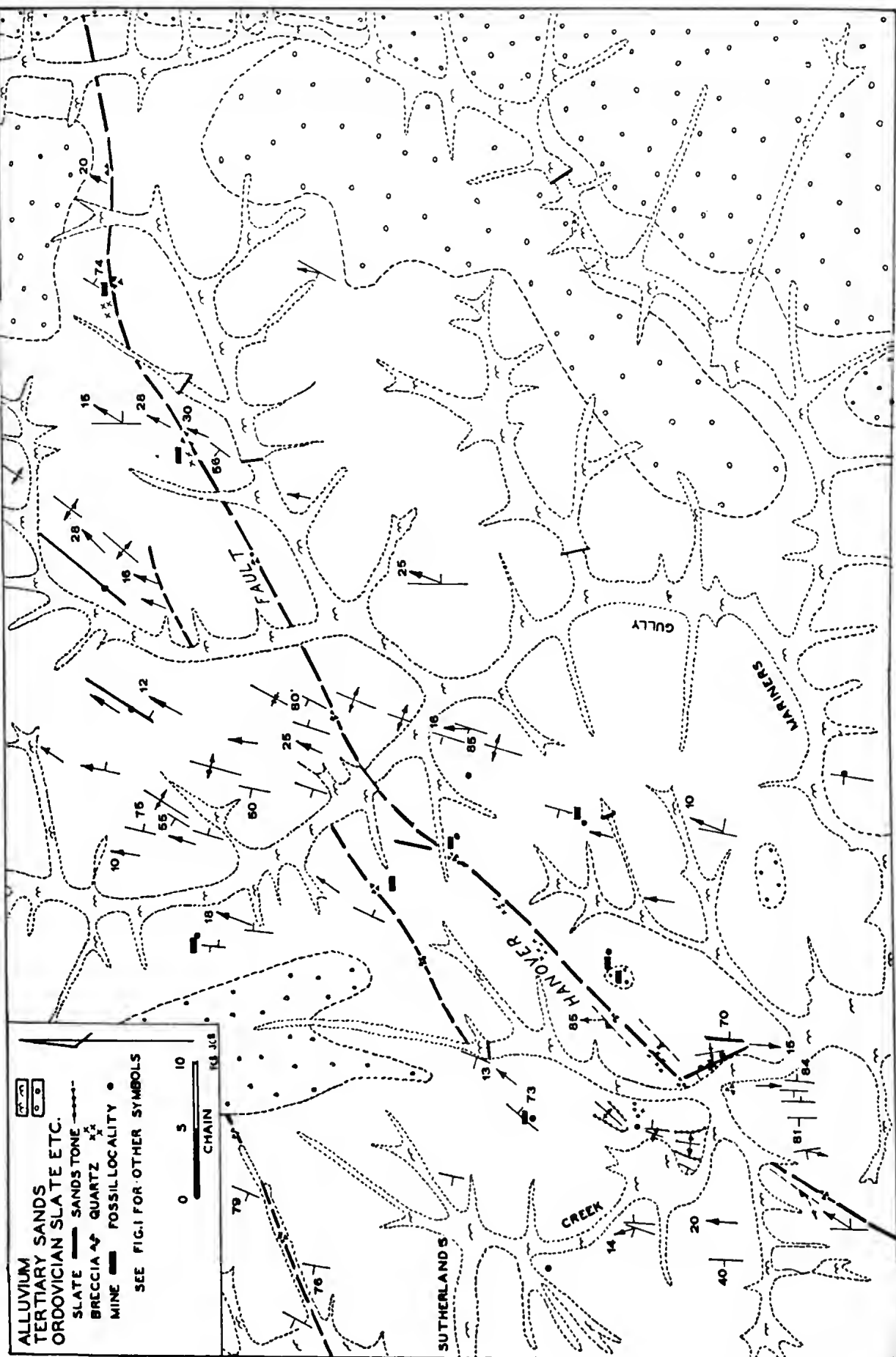


FIG. 8—Geological map of the Hanover Fault in the Mariner's Gully area.

the fault as of the order of 2000 ft. We agree that the evidence of macroscopic structure supports the concept of thrusting, but believe that there was a considerable component of strike slip indicated by such phenomena as drag of planar and linear structures.

In Long Gully, there is evidence of faulting similar to that observed at Mariner's Gully. Brecciation over a relatively narrow zone (5-10 ft) was noted. Here, the fault has an almost due northerly trend, with high Castlemainian beds abutting against low Darriwilian. Associated with the fault here, also, is a minor fault to the E., marked by brecciation. Some mineralization is evident in this area, but it is associated with the minor fault, and not with the main structure. Here, there is little evidence of drag: this may be due to the fact that, in Long Gully, the bedding and fault are almost parallel. There is, however, some sign of drag in abnormally steeply plunging fold axes.

In Long Gully, the Hanover Fault curves round from its NE. trend to northerly and, as well as a fine superposed cleavage parallel to the fault, there is locally a fine cleavage which, from the few observations, appears to be disposed radially to this curvature.

North of the Anakie-Steiglitz road, the Ordovician rocks are overlain by Cainozoic sediments, and the Hanover Fault is not exposed. Further N., on Stony Creek between Durdidiwarrah and Staughton Vale, outside the area studied here, Castlemainian and Yapeenian beds abut against Darriwilian, the boundary being a N.-S. fault. This is almost certainly a northerly extension of the Hanover Fault.

(b) **The Rowsley Fault:** A well preserved, slightly dissected, E.-facing escarpment marks the line of the Rowsley Fault. Fenner (1918) regarded this structure as a normal fault, downthrown to the east, on which displacement occurred comparatively late in the history of the area. Other workers are at present studying the relationship of the fault to Cainozoic rocks: we have confined our attention to the Ordovician sediments. The fault escarpment has an almost N.-S. trend, with a slight but significant flexure N. of Anakie township and immediately W. of Mt. Anakie. Difference in level across the escarpment is of the order of 350 to 450 ft.

Study of the Ordovician rocks along this escarpment has led us to conclude that it is due to late normal faulting along an older fault line, on which the earlier movement was possible thrusting due to compressive stresses. The flexure referred to above is the result of deformation of the old fault by the Anakie Monoform. Evidence which leads to this conclusion includes mesoscopic structures which could be induced only by shear stresses, and not by tensile stresses required for normal faulting. The evidence includes, particularly, crenulation cleavage in the Ordovician sediments, parallel to the escarpment, and crumpling of bedding both on a small and large scale. In spite of the sharpness of the escarpment, and some excellent exposures in ravines, we did not observe the actual fault zone. Immediately E. from the fault, the only exposed rocks are Newer Volcanics and Devonian granites: it is thus impossible to determine in this area the stratigraphic displacement on the original fault. The width of the contact metamorphic rocks W. from the escarpment is sufficiently great to suggest that the displacement was of no very high order of magnitude.

(c) **Minor Faults:** Three minor faults, all associated with the Hanover Fault, were noted above. Several other small faults were recorded, all with small displacement, and all roughly parallel to the strike of the Ordovician rocks which they disrupted. One of these occurs near the Anakie Monoform, and two N. of

Steiglitz township. Other minor faults almost certainly occur but poor exposure, and the nature of this study, precluded the possibility of the detailed field work required to record them.

(d) **Age of faulting:** No direct evidence of the age of either the Hanover Fault or the initial movement on the Rowsley Fault exists. The latest movement on the Rowsley Fault was more or less contemporaneous with the Newer Volcanic activity of Mt. Anakie and related centres. The Hanover Fault, overlain by Cainozoic sediments is certainly pre-Tertiary in age. The nature of the crush zone suggests that at the time of disruption, the rocks were in a brittle condition: a conclusion supported also by the nature of the superposed cleavage associated with the fault. Assuming that mineralization of the fault was associated with granitic intrusion, it could then be concluded that the fault pre-dated intrusive activity. However, there is virtually no evidence to support the basic assumption. There is no direct evidence of the age of the initial movement on the Rowsley Fault. The geometric relationship and the similar forms of deformation of this fault and the Hanover Fault suggest contemporaneity, but there is no conclusive evidence. The Rowsley Fault certainly predated the Anakie Monoform, and, since reasonable confining pressure would have been required for this flexure to develop as such, and not as a fracture structure, it is concluded that erosional uncovering was slight at the time, and the depth of burial reasonably great.

(iv) STRUCTURE AND ORE DEPOSITION

Active gold mining in the Steiglitz gold field ceased in the early years of this century. Gold was won economically from two main areas: the 'Central Area' about the township of Steiglitz, and the Mariner's Gully area. The only workings we noted outside these two areas were on Coolegurbark Ck and on a spur rising W. from Long Gully. Both these were shallow, and apparently unproductive. The only economic ore bodies were located on the Anakie Anticlinorium. In the Mariner's Gully Area, ore bodies were localized on the Hanover Fault, but even here, fault mineralization has occurred only along that part of the fault which cuts the hinge zone of the Anticlinorium. In the central area ore bodies occur in zones ranging from Ch2 to Ca3 so that a stratigraphic control of ore deposition cannot be accepted. The ore deposition was centred on the hinge zone of the Steiglitz Anticlinorium, and the gold field is limited by this structure.

The Hanover Fault forms the southern and eastern boundaries of the gold field. Because of the cover of Cainozoic rocks, the northern boundary is not known. However, the breaking up of the Steiglitz Anticlinorium to the N. of the area mapped suggests that here the economic ore also terminated.

Discussion of Structure

Three major macroscopic folds occur in the Steiglitz area: the Moorabool Synclinorium; the Steiglitz Anticlinorium, on which deposition of gold was localized; and the Anakie Synclinorium, separated from the other two macrofolds by the Hanover Fault which forms the southern and eastern boundaries of the Steiglitz gold field. The Anakie Monoform has locally deformed the folded Ordovician sediments and the Rowsley Fault.

One of the more interesting features of the structure in the Steiglitz area is the pattern and geometry of folding. The folds have an *en echelon* pattern, with fold hinges trending almost N.-S. Reversal of plunge occurs on discontinuous NE.-SW. axes, which also have an *en echelon* pattern. The total geometry is a triclinic $B \wedge B'$ type. With the exception of the Anakie Monoform, which has uniquely

37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82

[illegible]

During the close examination of some hundreds of specimens, only one new species was recognized: *Isograptus pertensa* (Harris). Several *Didymograpti* and one *Pterograptus* may be new species, but the specimens were too poorly preserved for detailed study. These specimens, however, have been lodged in the collection of the Geology Department, University of Melbourne (Nos. 3676, 3677, 3678) for possible future study. Formal description of *I. pertensa* is given here. Otherwise only incidental reference is made to morphological characters. Table 1 lists the representative collections made during the survey.

CHEWTONIAN FAUNA

The lowest zone recorded in the Ordovician rocks was that of *Didymograptus protobifidus* (Ch2). Beds of this zone are exposed along the hinge zone of the Steiglitz Anticlinorium. Ch3 beds were not recorded between Ch2 and Ca1, and it is possible they were not deposited, or are so thin that, in spite of careful search, they were passed over during the survey. At Morrisons, to the north west of the area studied, Harris and Thomas (1949) recorded relatively strong development of this zone. The following species were collected from Ch2 beds at Steiglitz.

- Didymograptus* cf. *D. extensus* J. Hall
- Isograptus caduceus* var. *primula* Harris
- Phyllograptus* cf. *P. typus* J. Hall
- Phyllograptus* sp.
- Dichograptus separatus* Elles
- Didymograptus* cf. *D. extensus* J. Hall
- Dichograptus octobrachiatus* J. Hall
- Tetragraptus bryonoides* J. Hall
- Tetragraptus serra* Brongniart
- Tetragraptus quadribrachiatus* J. Hall

Morphologically, the zonal fossil *Didymograptus protobifidus* exhibits a wide variability. The most prominent of these variations is the range in angle of stipe divergence, which is proximally 80°-110°, and distally, 10°-45°, figures which compare closely with those recorded by Ripper (1937). At Steiglitz, the increase in angle of divergence is accompanied by an increase in width of stipes, but all variants occur together, and because of the restricted thickness of the Ch2 beds, no conclusion can be reached concerning the evolutionary significance, if any, of these features.

I. caduceus var. *primula* is a small form which seems to be restricted to the upper beds of the zone, and marks transition to Ca1. *Phyllograptus* cf. *typus* is also a relatively common species. Extensiform *Didymograpti* are rare: a few specimens of *D. cf. extensus* were collected (loc. 41).

CASTLEMAINIAN FAUNA

In spite of the wide distribution of Castlemainian beds, fossil localities are by no means common, and we are forced to conclude that great thicknesses of the Castlemainian beds in this area are unfossiliferous. The fauna is characterized by variants of *Isograptus caduceus*, and these are always the most abundantly occurring forms at any locality. The Ca1 fauna includes:

- Isograptus caduceus* var. *primula* Harris
- Isograptus caduceus* var. *lunata* Harris
- Phyllograptus angustifolius* J. Hall

for the area, affected the B folds, and is clearly associated with superposed structures, the triclinic $B \wedge B'$ symmetry generally in the Steiglitz area does not imply separate, unrelated folding deformations. So far as we can ascertain (Whitten 1966 and references) most examples of this fold geometry through the world would have been ascribed to two (or more) foldings. Here, however, there is evidence of one deformation only.

The folding mechanism involved both flow and flexural slip with localized flow in the siltstones and sandstones, with considerable transposition along cleavages in fold hinge zones in siltstones, and throughout the folds in slates. With such folding mechanism, elongation parallel to the fold axes, B, was an important element of the movement picture. Prevention of movement parallel to B or restriction of this movement, together with the development of shear couples within the deforming mass in part as a result of this resistance, would produce a fold pattern with the geometry pattern and symmetry occurring at Steiglitz.

The field relationships of the Hanover and Rowsley Faults to the Anakie Monocline suggest a genetic relationship. Shear stresses to produce this monocline could be developed in the rock mass from the normal compressive stresses responsible for thrust movements on the faults.

The stresses responsible for the fault movements were also responsible for the superposition of some of the crenulation cleavage on the already folded rocks, and for some of the superposed linear structures in the previously folded slates. Other cases of superposed cleavage appear to be the result of stresses associated with igneous intrusive activity, and a few rare cases may be associated with localized stresses in developing parasitic 'drag' folds during the main folding.

Graptolites of the Steiglitz Area

Apart from incidental reference in various publications by Harris, Harris and Thomas, and Harris and Keble, the only record of the graptolites in the Steiglitz area is that of T. S. Hall (1913) which is simply a list of forms from a few of Ferguson's (1940) localities. During the present survey, over 50 species were collected from almost 100 localities, as well as a number of specimens too poorly preserved for specific identification, notably *Tetragrapti* and *Phyllograpti*. Even when well preserved, the *Phyllograpti* could often not be referred definitely to a particular species, and could be listed only as a comparison (Table 1).

The graptolites in the Steiglitz area are found in dense black or red-grey slates, although the fossiliferous Darriwilian Beds are grey, fawn and purple shales and slates and black pelitic hornfels. In the eastern sector of the area, where the sediments have been thermally metamorphosed, the graptolites are preserved in the hornfels as aggregates of fine golden mica flakes; all morphological detail has been destroyed by the metamorphism. Fossil localities were found more commonly in the Darriwilian and were least common in the Castlemainian.

Collection of specimens from obviously richly fossiliferous beds was often difficult due to the acuteness of the cleavage-bedding intersection (particularly in the central sector of the area) and the deep weathering of the rocks.

The fauna is dominated by Isograptids which appear in the oldest beds of the area (Chewtonian, Ch2) and which persist through to the lower parts of the Darriwilian (Da1).

In quantitative terms, the Isograptids reached the peak of their development in the Yapeenian and in the Darriwilian gave way to the Diplograptids which dominate the fauna from Da1 through to the highest beds in the area, Da3.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34

[illegible]

Phyllograptus cf. *P. typus* J. Hall
Didymograptus extensus J. Hall
Didymograptus nitidus J. Hall
Tetragraptus bryonoides J. Hall
Tetragraptus serra Brongniart

I. caduceus var. *primula* was collected from one locality only (45), about midway through the Ca1 sequence; var. *lunata* is the dominant isograptid of this fauna.

Ca2 forms include:

Isograptus caduceus var. *victoriae* Harris
Phyllograptus angustifolius J. Hall
Phyllograptus sp. (small form)
Dichograptus octobrachiatus J. Hall
Didymograptus extensus J. Hall
Tetragraptus?bryonoides J. Hall
Tetragraptus serra Brongniart
Tetragraptus similis J. Hall

D. octobrachiatus is rare, and was collected only at loc. 32; *I. caduceus* var. *victoriae* was abundant at all localities.

The uppermost Castlemainian beds are particularly unfossiliferous, and the fauna is a narrow one. The zone fossil *Isograptus caduceus* var. *maximus* is always abundant, but was sometimes the only species collected. Occasionally var. *victoriae* was found: this was not restricted to the lower part of the zone, but was also found in beds transitional to the Yapeenian. Some localities referred to transitional Ca3-Ya1 included *I. caduceus* var. *divergens* with abundant var. *maximus*. The Ca3 fauna is:

Isograptus caduceus var. *maximus* Harris
Isograptus caduceus var. *victoriae* Harris
Isograptus caduceus var. *divergens* Harris
Phyllograptus angustifolius J. Hall
Didymograptus spp.

YAPEENIAN FAUNA

The zonal fossils *Oncograptus upsilon* and *Cardiograptus morsus* are not found typically in the Yapeenian assemblages. The Ya1 fauna includes:

Oncograptus upsilon Harris and Keble
Isograptus caduceus var. *maximus* Harris
Isograptus caduceus var. *divergens* Harris
Isograptus caduceus var. *victoriae* Harris
Isograptus pertensa (Harris)
Loganograptus logani J. Hall
Phyllograptus spp.
Didymograptus extensus J. Hall
Didymograptus spp.

Oncograptus upsilon was collected only at localities 57, 73 and 74. *I. caduceus* var. *divergens* is the most abundant fossil. *I. caduceus* vars. *maximus* and *victoriae* are found only sporadically, and then low in the zone. *Loganograptus logani* appears at the base of Ya1 and is a typical Yapeenian form. One of the most interesting aspects of the fauna is the occurrence of *Isograptus pertensa*

(Harris). This species, described as a variety of *I. caduceus* by Harris (1933) had been recorded only from Darriwilian beds on Sutherland's Creek. Its occurrence at loc. 68 on the Moorabool R., Sheoaks, in beds transitional from Ca3 to Ya1 extends its range downwards considerably, and demands a review of its genetic relationships.

The Ya2 fauna is an exceptionally rich one, but, like the Ya1 fauna, it is dominated by variants of *I. caduceus* and closely related species:

Cardiograptus morsus Harris and Keble
Isograptus caduceus var. *divergens* Harris
Isograptus caduceus var. *maximus* Harris
Isograptus caduceus var. *maximo-divergens* Harris
Isograptus forcipiformis Ruedemann
Isograptus hastatus Harris
Isograptus manubriatus T. S. Hall
Didymograptus v-deflexus Harris
Didymograptus distinctus Harris and Thomas
Didymograptus ?n. sp.
Didymograptus sp.
Pterograptus ?n. sp.

Isograptus hastatus (locs. 54, 55, 56) and *I. manubriatus* (loc. 56) are comparatively rare. *I. hastatus* was recorded from Steiglitz by Harris (1933) but *I. manubriatus* has not been recorded previously from this area. *I. hastatus* appears several hundred feet lower in the sequence than *I. manubriatus*. The two species are found together in a synclinal hinge near the top of the Yapcenian, while *I. manubriatus* was recorded even higher in the sequence from Da1 (loc. 76).

DARRIWILIAN FAUNA

At the top of Da1, the Isograptid fauna is extinct, and except for an occasional locality at the base of the zone, the fauna throughout the Darriwilian is Diplograptid. The Da1 fauna includes:

Glytograptus austradentatus Harris and Keble
Trigonograptus wilkinsoni T. S. Hall
Lasiograptus etheridgei Harris
Glossograptus hincksii Hopkinson
Cryptograptus tricornis Carruthers
Phyllograptus sp. (small form)
Isograptus caduceus var. *divergens* Harris
Isograptus caduceus var. *maximo-divergens* Harris
Isograptus manubriatus T. S. Hall
Isograptus pertensa (Harris)
Didymograptus sp.

In some areas, particularly at loc. 50, the fauna was extremely rich, but advanced metamorphism prevented specific determination. The Da2 beds contained:

Glyptograptus intersitus Harris and Thomas
Glyptograptus austrodentatus Harris and Keble
Trigonograptus wilkinsoni T. S. Hall
Cryptograptus tricornis Carruthers
Didymograptus cf. *d. v-deflexus* Harris

Didymograptus spp.

Tetragraptis sp.

Didymograptus cf. *v-deflexus*, recorded from loc. 25 may be a new species, but the material collected was insufficiently well preserved for a definite decision. At loc. 25, a richly fossiliferous bed, which could be traced for some 60 chains contained abundant *Didymograpti*. Unfortunately, the specimens were so thickly arrayed that specific identification was impossible.

The Da3 beds have a very restricted fauna:

Diplograptus decoratus Harris and Thomas

Glossograptus acanthus Elles and Wood

Didymograptus spp.

Da3 beds are quite thin and marked the top of the Ordovician sequence of Steiglitz. Exposures were restricted to synclinal hinges.

DESCRIPTION OF SPECIES

Isograptus pertensa, Harris

Isograptus caduceus var. *pertensa* W. J. Harris, *Proc. Roy. Soc. Vict.* 46 (1) Fig. 31, 1933.

DESCRIPTION: Rhabdosome large, scandent, consisting of two stipes 8 to 10 cm long, diverging at an angle of 340° . After initial divergence, the stipes are straight, with a width of 3 mm proximally, tapering to 1.5 mm distally. The thecae are spinose proximally, and number 7-8 in 10 mm. Distally, the thecae are slightly denticulate, sometimes lobate, with downward directed mucros, and number 6-7 in 10 mm. The sicular region is thick and spinose and the sicula is 6 mm long. A fine nema may be present.

REMARKS: Harris, who gave no formal description, regarded this form as a probable catagenetic ally of *I. caduceus* var. *divergens*. The wide variation in a number of diagnostic features of *Isograptus caduceus* were not fully studied by Harris, and there are, in *I. pertensa*, important morphological characters which lie outside the limits of variation in *I. caduceus*. The denticulate nature of the thecae is usually more pronounced than in *I. caduceus* while lobate thecae occurring distally are not found in *I. caduceus*. The angle of divergence of the stipes is significantly greater, and the width:length ratio of the stipes is considerably less; the sicular region is relatively thicker and more spinose.

Number of thecae in 10 mm varies from 8 proximally, to 6 distally; and the thecal openings are directed downward. In the proximal region the apertural margins of the thecae are straight; distally, they are concave.

In the 20 specimens collected from 3 localities there is little variation in the features described. Preservation of the whole rhabdosome is never good, and detail of the proximal and distal ends can rarely be studied in the same specimen.

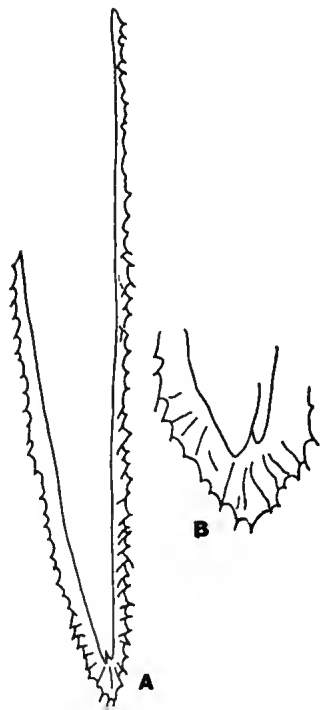


Fig. 9

- a. *Isograptus pertensa* (Harris)
Detail of proximal region.
Moorabool R. Sheoaks.
- b. *Isograptus pertensa* (Harris)
Sutherland's Ck. Steiglitz
(Geol. Surv. Vict. 6719)

Isograptus pertensa was collected from Ferguson's locality S_x 57 (loc. 13) on Sutherland's Ck, Steiglitz; from a southerly continuation of this bed (loc. 31) and from the south bank of the Moorabool R. at Sheoaks (loc. 68).

At the first of these localities the faunal assemblage is typically Da1. At loc. 68 the assemblage is transitional Ca3-Ya1. The range of *I. pertensa* is at least Ya1 to Da1.

Acknowledgements

We wish to record our appreciation of the following: The late Dr W. J. Harris for indicating some of the problems and for pointing out the interest of the mesoscopic structures; Adrian Beavis and students of Melbourne University in locating and collecting graptolites; the Geological Survey of Victoria for permitting us to examine Ferguson's graptolite collection, and type specimens of *Isograptus caduceus*; and to the University of Melbourne for a research grant which covered the cost of the field work, and also for payment of part of the cost of publication.

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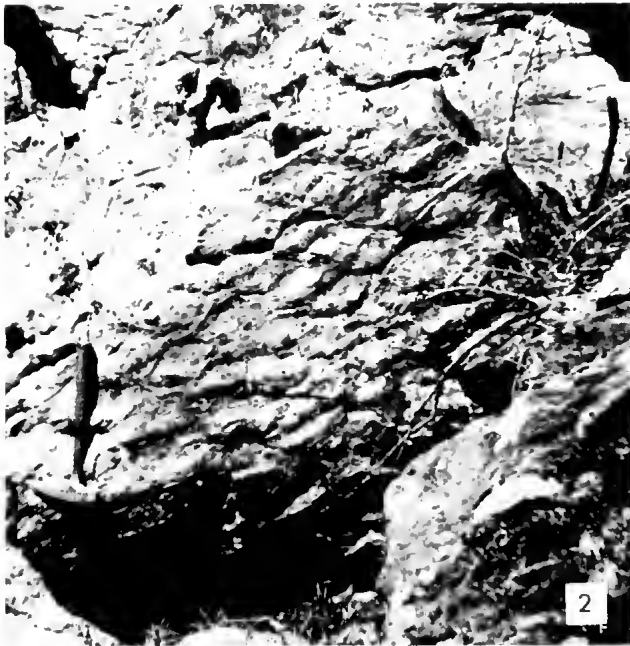
Description of Plates

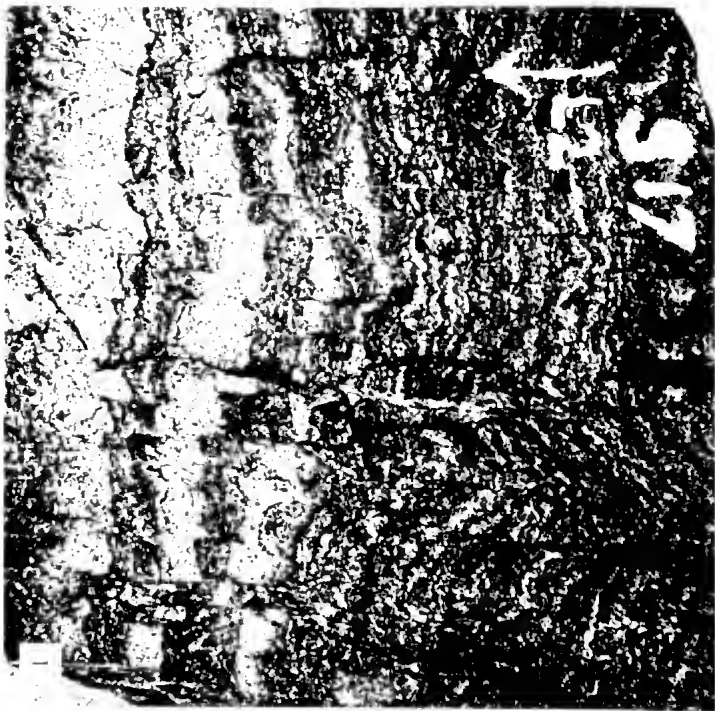
PLATE 9

- Fig. 1—Folds in sandstones, Moorabool R., Steiglitz-Meredith Road, Facing north. Note steep west dipping limbs. Length of section 15 ft. (A. P. Beavis photo)
 Fig. 2—'Lozenge Structure' in sandstone. Grahame's Gully, Steiglitz. (A. P. Beavis photo)

PLATE 10 (natural size)

- Fig. 1—Photograph of cleavage plane (S1) showing lineation L1 deformed by S2. Lineation L2 is the fine fracture lines. Hanover Fault—Mariner's Gully.
 Fig. 2—Conjugate L2 of siltstone with L1 trending diagonally across specimen. Ingliston.
 Fig. 3—Crenulate lineation L2 in S1 of slate. L1 appears as fine deformed black lines. De Mott's Road, Anakie.
 Fig. 4—Fine crenulate lineation L2 in cleavage plane S1 of cherty slate, Sutherlands Ck, Steiglitz.





STRUCTURES IN SCHIST, TAWONGA, VICTORIA, AUSTRALIA

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Abstract

Foliations and folds in chlorite-quartz-albite schists from Tawonga, N.-E. Victoria, are described. Micro-structural analysis has established geometric and genetic relationships between schistosity and F1 folds; and between kink bands, crenulation cleavage, and F2 folds.

Introduction

The northern slopes of the Symmond's Ck valley, near Tawonga, form the footwall of the Tawonga Fault. The rocks are deeply weathered, covered by hill-slope debris and alluvium, and therefore exposures are poor. In the floor of the valley, about 3 miles upstream from the junction of Symmond's Ck with the Kiewa R., chlorite-quartz-albite schists are sufficiently well exposed to permit a study of the structure of these rocks: the lowest grade of crystalline schists occurring on the western margin of the Metamorphic Complex, within the Complex itself.

The Symmond's Ck.—Tawonga Gap area lies within the zones of the Tawonga Fault and the West Kiewa Thrust. Its geology is far from simple. Immediately S. of the exposures described in this paper the Tawonga Thrust plane is exposed, and the chlorite-quartz-albite schist is overlain by crushed brecciated quartz feldspar-sillimanite gneiss (Fig. 1). Immediately to the N. is a complex belt of gneiss, high and low-grade schists, mylonites, greywackes and slates, which obviously represents a major crush zone.

The work described in this note established, for the first time, the existence of two generations of folds on both microscopic and mesoscopic scales, in the crystalline schists. Previously, multiple folding had been recognized in the sediments bordering the Metamorphic Complex, but no evidence of such deformation had been found in the Complex itself (Beavis 1963, 1964, 1965).

The help in the field of Mrs. Joan Beavis and Mr. F. Himing is gratefully acknowledged.

Mesoscopic Structure

The schists of the Symmond's Ck area appear to have a single foliation, S1, emphasized by laminae of chlorite alternating with laminae composed essentially of quartz and albite. This foliation is crenulated, the axial surfaces of the small folds having a steep dip and an axial surface separation of 1 to 2 cm. The axial surfaces do not constitute a prominent foliation on the mesoscopic scale. The hinges of the crenulations form S.-E. and N.-W. plunging linear structures in the schistosity, while on the schistosity planes there is occasionally visible a deformed colour banding lineation which appears to represent a trace of original bedding.

Foliation S1 is sub-parallel to the surfaces separating thick pelitic layers from thick arenaceous layers; these surfaces have been interpreted as original bedding

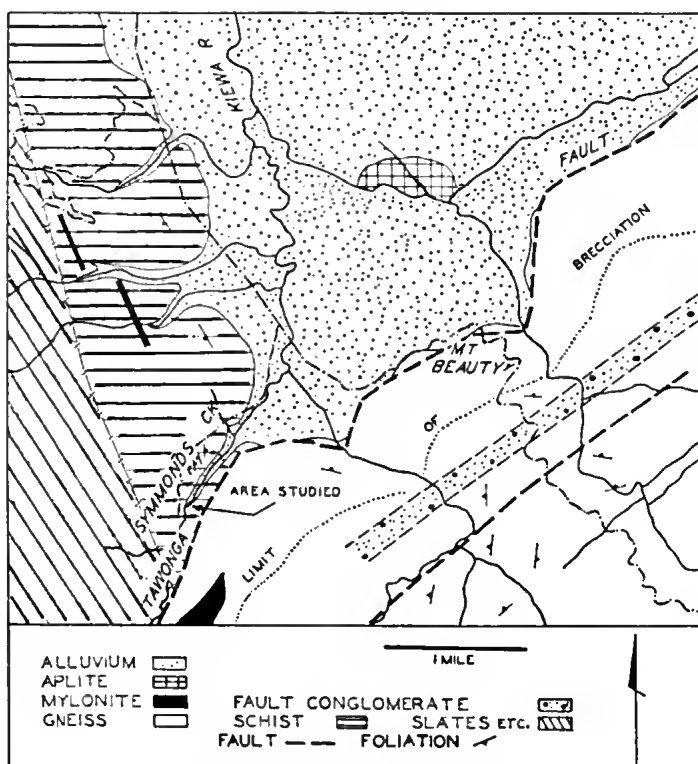


FIG. 1—Locality map, showing geology in the area studied.

planes (S_0). The bedding planes, as well as the foliation, have been deformed into relatively large mesoscopic folds, whose profiles can be seen in the road cutting. The folds may be quite sharp and tight, or may be open. Since the foliation S_1 is a form surface of the folds, they are interpreted as second generation F_2 structures.

Microscopic Structure

Because of poor outcrops and deep weathering, little can be learned of the structure of the schists on a mesoscopic scale. A series of oriented specimens was faced for microscopic examination, and a series of oriented thin sections were prepared for qualitative and quantitative microscopic study.

(i) FOLIATIONS. With microscopic examination, three sets of surfaces can be recognized in the schists: bedding (S_0); schistosity (S_1) emphasized by a lithological layering; and kink bands with rare crenulation cleavage (S_2). The kink bands and crenulation cleavage are restricted to pelitic laminac. The lithological layering, consisting of thin discontinuous laminac or quartz and albite, alternating with thicker, more continuous laminac of chlorite with fine needles of quartz, is essentially parallel to the fine schistosity of the chlorite laminac formed by the preferred orientation of the chlorite flakes and quartz needles. The thicker quartz-albite layers show a quite definite and consistent gradation of grain size, and in some quite specific domains are cut by the schistosity. These facts suggest

that the lithological layering represents original bedding, almost completely transposed by the schistosity *S*1, into the plane of schistosity. This conclusion is confirmed by the existence of microfolds (Fig. 2) in the quartz-albite laminae, and to a lesser extent in the chlorite laminae, the axial planes of which are the schistosity *S*1. These microfolds are *F*1 structures. After transposition, the laminae were subsequently deformed by a second folding, the small folds so formed being kink bands, sometimes with crenulation cleavage as axial surfaces. On the prepared faces, and in thin section, the kink bands and crenulation cleavage form a distinctive foliation *S*2 but this cannot be readily distinguished in the field.

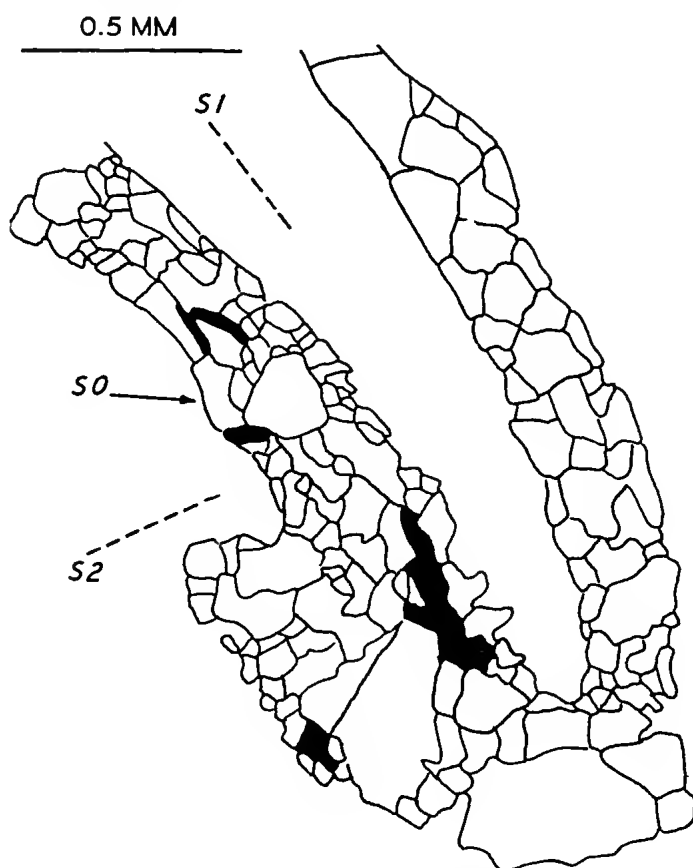


FIG. 2—*F*1 folds in quartz-albite lamina.

As noted above, the kink bands are restricted to the chlorite layers. Their boundaries are rarely planar, but have a distinct curvature: moreover, within any one lamina the dip of kink bands may vary through a range of 50° (Fig. 4). Where they are interrupted by quartz-albite laminae, the kink bands are refracted by as much as 30° , after which they gradually curve back to a normal attitude. Curvature of the kink bands generally appears to be associated with gradation in texture of the chlorite. The width of kink bands varies between 0.1 and 2.0 mm but the width of an individual band is by no means constant. Several bands may converge to

form a single wide band; a band may decrease in width and gradually die out, or it may terminate quite sharply. Sometimes, with narrowing, the kink bands pass into a crenulation cleavage, the transition being achieved by increasing rotation of the chlorite flakes.

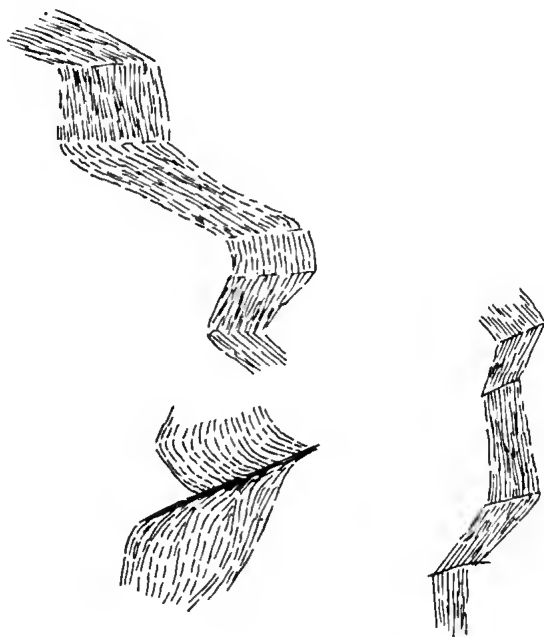


FIG. 3—Styles of kink bands.

In a recently published work, Dewey (1965) recognized four geometric classes of kink band, each with unique characteristics, in whose formation strains and mechanisms differed markedly. Of Dewey's types, two occur in the rocks under discussion: segregation kink bands, and shear kink bands. In some isolated instances, the former occur as *en echelon* second-order sets, usually in antiformal hinge zones. Apart from this, there is no restriction on the distribution of the two types which may occur as adjacent bands (Fig. 3). The segregation kink bands are reverse types with kink planes developed only rarely; these are never planes of total strain discontinuity. Fine accumulations of quartz may occur along the kink planes. The shear kink bands are both normal and reverse; the kinks have well rounded hinges, and the style is 'similar'. It is this type which passes into crenulation cleavage.

(ii) FOLDS. Microscopically, two generations of folds can be distinguished: the first-generation F1 folds have been obliterated to a large degree by transposition, but a few remnant F1 hinges have been preserved. The form surfaces of these folds is S_0 , with S_1 forming the axial surfaces. The second-generation folds, F2, occur on three scales: the microscopic kink bands in S_1 ; the mesoscopic crenulations in the lithological layering with S_2 as axial surface, and with axial plane separation of 1-2 cm; and large mesoscopic folds in S_0 and S_1 , with axial plane separation of up to 100 ft. The microscopic F1 folds are more readily

recognized in the quartz-albite laminac, where the hinges are tight, and the limbs drawn out to the thickness of a single grain. The hinge zones are thickened, but maximum thickness occurs to one side of the hinge proper. Often, these folds have been completely closed, so that the two limbs are in contact along the axial surface. The total effect of this is to produce a localized thickening of the lamina.

The F2 microscopic folds include kink bands, but if this style is excluded it can be stated that the F2 folds have for the most part rounded hinges, although some are sharp and even cusped. The geometry approaches that of the ideal similar style fold (Fig. 4). Anomalous thickening of the limbs of F2 folds is associated with F1 fold hinges.

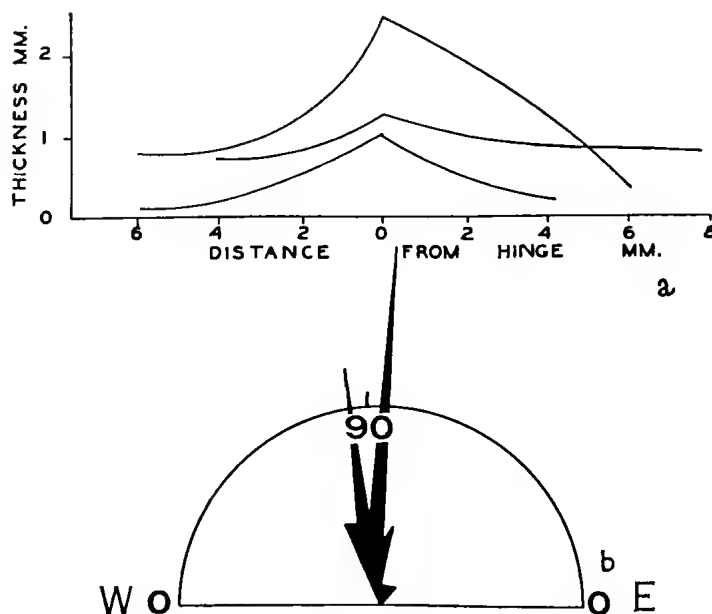


FIG. 4—*a.* Geometry of chlorite lamina indicating 'similar' style of folds.
b. Dip of kink bands in a chlorite lamina. Radius of circle represents 10 bands.

(iii) MICROSTRUCTURE OF THE QUARTZ-ALBITE LAMINAE. Qualitative examination of the quartz-albite laminae suggests a dimensional orientation of the quartz and albite grains (Fig. 6a). Dimensional orientation, however, depends on the thickness of the layer; for the thicker layers, the long axes and long edges of quartz and albite grains are parallel to S₂ and produce a crude foliation. In the layers which are only one or two grains thick any dimensional orientation developed is such that the long axes of grains are parallel to S₁ (Fig. 6b). This evidence indicates that, although there was no excessive elongation of the quartz, both F₁ and F₂ deformations involved some rotation of the quartz and albite grains.

Orientation of [0001] quartz was determined in the quartz-albite laminae and shows a high degree of homogeneity, the only departure from the standard pattern occurring in F₁ fold hinges.

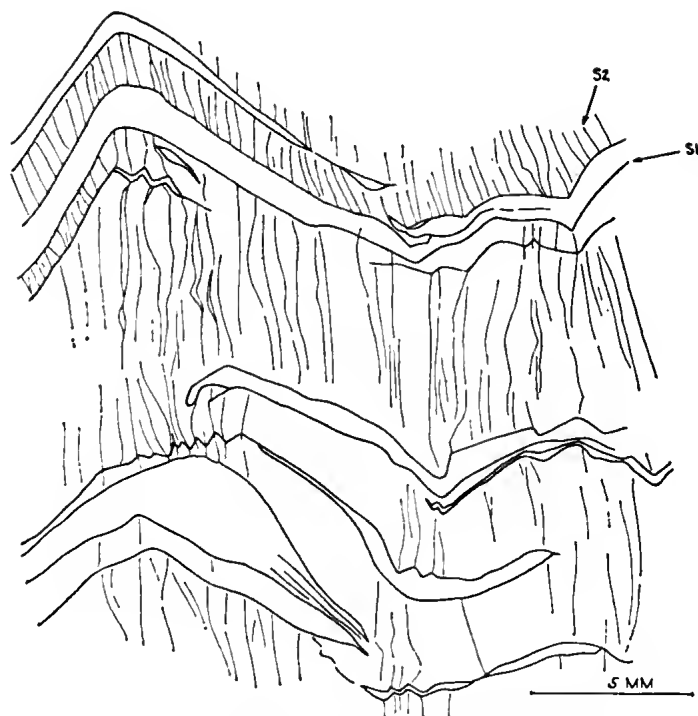


FIG. 5—F2 folds in chlorite-quartz albite schist.

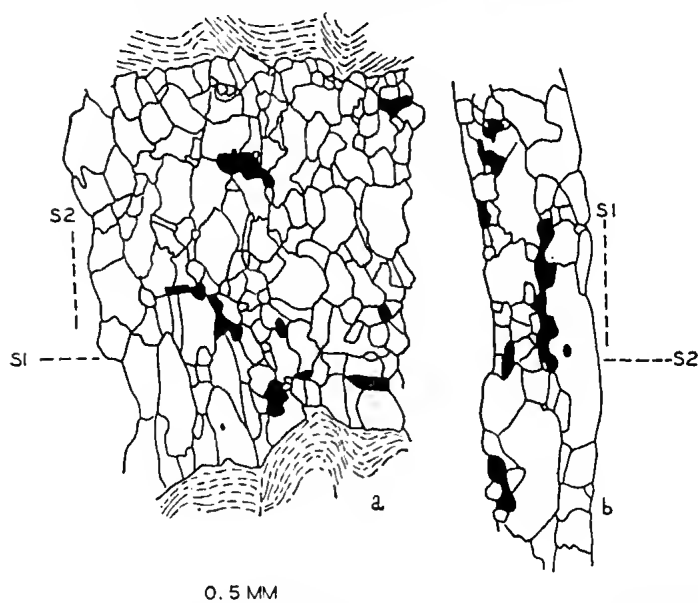


FIG. 6—Preferred dimensional orientation of quartz in quartz albite laminae.
 a. Thick lamina: long axes lie parallel to S2.
 b. Thin lamina: long axes lie parallel to S1.

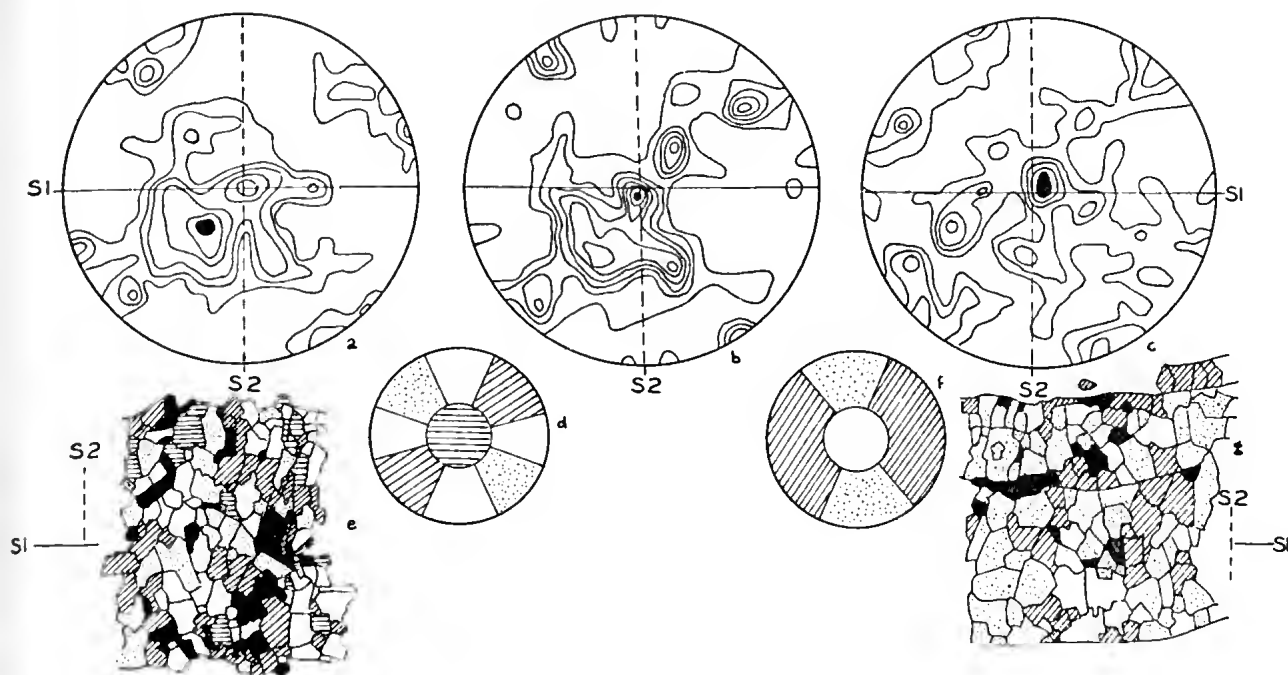


FIG. 7—*a.* 127 [0001] quartz in quartz albite lamina forming limb of F2 fold.

Contours 1, 2, 3, 5, 10, 15%

b. 112 [0001] quartz in quartz albite lamina at hinge of F2 fold.

Contours 1, 2, 3, 4, 5, 7, 9%

c. 93 [0001] quartz in quartz albite lamina at hinge of F1 fold.

d. Direction groups of figure 7*a.*

e. A.V.A. of area analysed in figure 7*a.*

f. Direction groups of figure 7*b.*

g. A.V.A. of area analysed in figure 7*b.*

Three of the analyses are shown on Fig. 7. Deformation lamellae are present in a few quartz grains. These appear to be symmetrical about S2 and have orthorhombic symmetry, but, since only 23 grains showed lamellae, the data are inadequate for further discussion. Fig. 7*a* shows the orientation of [0001] quartz in the limb of an F2 fold; Fig. 7*b*, in the hinge of an F2 fold; Fig. 7*c*, in the hinge of an F1 fold. All diagrams have two partial girdles oriented symmetrically with respect to S2. In addition, the diagram for the F1 fold shows a girdle lying in S1.

A.V.A. of the two domains of Fig. 7*a* and 7*b* are shown respectively in Fig. 7*d* and 7*e*; and 7*f* and 7*g*. This analysis suggests two domains, one lying in S1 and one in S2. If this interpretation is correct, the orientation of the quartz is the combined result of the F1 and F2 deformations.

Discussion

The evidence is quite conclusive, that the chlorite-quartz-albite schists at Symond's Ck, Tawonga, have been subjected to two folding deformations. The mechanism of the F1 folding was by slip or flow on S1 with a limited amount of slip on S0. Movement on S1 was extreme, leading to an almost complete trans-

position of S₀ into S₁. At the same time, deformation was accompanied by considerable recrystallization. It would be expected that the work of Dewey on kink bands (op. cit.) would lead to the use of these structures to determine the mechanism of the F₂ folds. Dewey reasoned that segregation kink bands were formed by flexure with dilation normal to the band, indicating rapid deformation at a high structural level. Shear kink bands on the other hand were stated to indicate slow plastic distortion. This apparently anomalous situation in the Tawonga schists, where both types occur together, doubtless arises because Dewey argues from idealized mathematical models which do not always approach actual physical conditions.

The evidence is clear, nonetheless, that the F₂ folding involved a flexural slip mechanism, although it is not possible to assess the tectonic environment. Active planes of movement which would have formed had folding been by slip or flow on S₂ are so weakly developed that this mechanism cannot be regarded as having played a significant role.

Acknowledgements

I wish to thank the University of Melbourne for payment of part of the cost of publication of this paper.

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Description of Plate

PLATE 11

Fig. 1—Photomicrograph (× 20) of schist showing kink bands (S₂) in S₁.



LITTORAL AMPHIPODA OF VICTORIA PART II

By H. J. FEARN-WANNAN

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Abstract

A new species of Victorian Amphipoda, viz. *Orchestia australis*, is described and figured, and the occurrence of two other well known species from this order in Victorian waters is recorded.

Introduction

This paper describes a new Victorian Amphipod species which has been observed in the euryhaline waters of Lake King (Gippsland) and in the marine waters of Port Phillip Bay and Western Port Bay. This new species belongs to the family Talitridae, a family which is morphologically adapted to both aquatic and terrestrial conditions.

The occurrence of well-known species of two other families, viz. Oedicerotidae and Corophiidae, is also recorded in this paper. At present our knowledge of the taxonomy of the Australian representatives of these families and, indeed, of the Australian Amphipods in general is sparse, and it is hoped that the ecological notes provided hereunder will prove valuable.

This work forms the second part of a comprehensive study of the ecological relationships of the Amphipoda of the major bays and inlets of the Victorian coastline. It is hoped that other aspects of this study will be dealt with in subsequent papers.

Family TALITRIDAE

Genus *Orchestia* Pallas

Orchestia Pallas 1766

Type species by original designation: *Orchestia gammarellus* (Pallas), 1766.

Orchestia australis, n. sp.

Fig. 1A-E, 2A-F

DIFFERENTIAL DIAGNOSIS: This form bears a fairly close resemblance to several established species of *Orchestia*. These are *O. bottae* (1840, Milne-Edwards), *O. gammarellus* (1766, Pallas), *O. chevreuxi* (1887, Guerne), *O. chiliensis* (1840, Milne-Edwards), *O. miranda* (1916, Chilton), *O. marmorata* (1881, Haswell) and *O. Macleayana* (1879, Haswell).

The major distinguishing feature of the new form is the thick fleshy telson which is deeply cleft. In none of the species listed above is the telson more than slightly emarginate at the apex.

Certain features of the 5th pereopod also enable a clear distinction to be drawn. For example, the 4th segment of the fifth pereopod in the new form is very slightly expanded distally, whereas in *O. bottae* this is not expanded, and in

O. gammarellus, *O. chiliensis* and *O. miranda* the distal end of the 4th segment of both fourth and fifth peraeopods is greatly expanded. In the new form the 6th segment of the fifth peraeopod is almost straight, whereas in *O. chevreuxi* this segment is markedly curved.

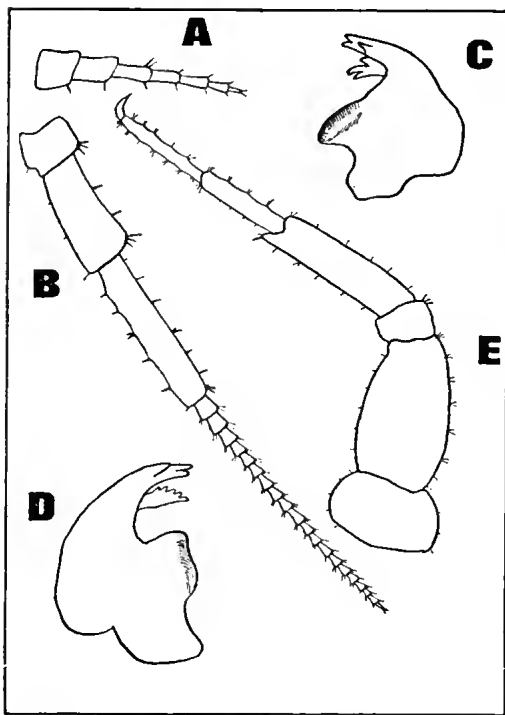


Fig. 1—*Orchestia Australis* (n. sp.)

A. Antenna 1 (c. $\times 27$); B. Antenna 2 (c. $\times 22$); C. Right Mandible (c. $\times 25$); D. Left Mandible (c. $\times 25$); E. Peraeopod 5 (c. $\times 15$).

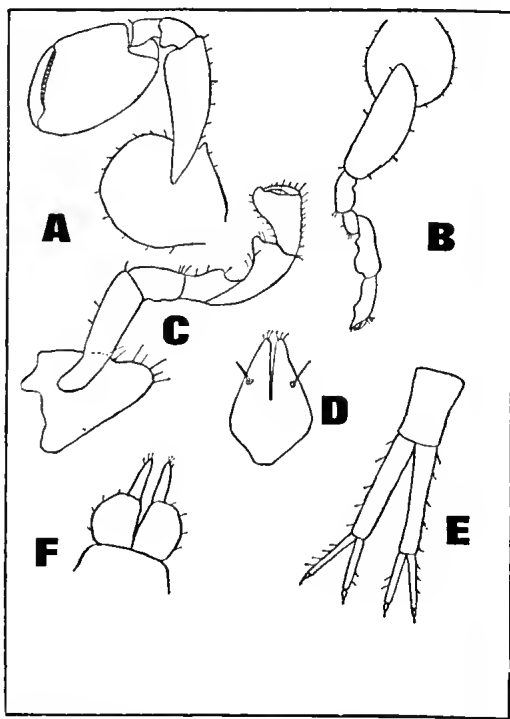


Fig. 2—*Orchestia australis* (n. sp.)

A. Gnathopod 2 σ (c. $\times 12$); B. Gnathopod 2 ϕ (c. $\times 15$); C. Gnathopod σ (c. $\times 20$); D. Telson (c. $\times 25$); E. Uropod 1 (c. $\times 20$); F. Uropod 3 (c. $\times 25$).

The sixth segment of the second gnathopod in the male of the new species has an oblique palm, not transverse as in *O. gammarellus*, and is ovate rather than widening to the palm as in *O. gammarellus*.

The new species probably bears closest resemblance to *O. Macleayana* which has been observed on the sandy beaches of New South Wales. However, the new species can be clearly differentiated from *O. Macleayana* on several grounds. Haswell (1882) has pointed out that the three posterior pairs of peraeopods in *O. Macleayana* increase progressively in length, the fourth pair much longer than the third, and the fifth slightly longer than the fourth. In the new species described hereunder the increment between the mean lengths of the third and fourth peraeopods is 0.6 mm whereas that of fourth and fifth peraeopods is 0.7 mm.

There is a difference too in palm structure. The palm of *O. australis* is smooth and slightly convex, whereas in *O. Macleayana* it has been described by

Haswell as waved. The latter species also possesses a small tooth on the posterior margin of the second joint of the fifth pereopod. The telson of *O. Macleayana* has been described as triangular and blunt. As indicated above, the telson of the new species is pointed, fleshy, and deeply cleft.

DESCRIPTION OF MALE: Maximum body length recorded, 13.0 mm; for the sample of 20 specimens examined, the mean length was 8.8 mm (S.D. = 1.7); depth of body about one quarter of the length of body. Head short, broader than long; prominent epistome. Rostrum greatly reduced. Eyes round, well developed, darkly pigmented.

Antenna 1—Recorded variation in length ranged from 2.0 mm to 0.5 mm with a mean of 1.0 mm (S.D. = 0.4) for the 20 specimens examined. Antenna 1 reaching just beyond penultimate segment of peduncle of antenna 2; first segment a little shorter, but half as wide again as second segment; third segment as long, but three-quarters of the width of second segment; flagellum short, 4-segmented. Accessory flagellum absent.

Antenna 2—The recorded variation in length ranged from 6.5 mm to 2.0 mm with a mean of 3.4 mm (S.D. = 1.1); Antenna 2, about one-third length of body; first segment short, almost as long as broad; second segment about 2.5 times as long as first, a little narrower; third segment half as long again as second segment but about half as wide; flagellum slightly shorter than the peduncle, about 20-segmented; each segment bearing a pair of spines in each distal angle.

Mouth Parts—Upper lip minutely setose at apex of broadly rounded distal margin. Right mandible, cutting edge coarsely toothed with about three strong teeth; secondary process powerfully tricuspid in appearance; spine row absent; molar process strongly denticulate, obliquely oriented. Left mandible, similar to right, secondary process not tricuspid in appearance but consisting of a 5-toothed blade. Molar process vertically oriented. Palp absent.

Maxilla 1, inner plate almost as long as outer, tapering to half its width at apex, heavily spined; outer plate broadening from base, about twice basal width at apex, heavily spined at truncated end; palp 1-segmented, terminating in two long setose spines. Maxilla 2, inner plate slightly shorter than outer, with a distal row of setose spines; outer plate a little wider than inner with a row of spines at the rounded end. Maxillipeds, inner plate small, with several rows of setose spines on rounded distal border and along inner surface; outer plate subovate, reaching almost to end of third segment of palp, the long curved inner margin furnished with several rows of heavy spines which lack setation; basos twice the length of ischium; palp consisting of three segments; the first segment about as long as ischium, a cluster of spines in the inner distal angle; second segment about as long as first, but considerably broader, the inner distal angle produced to form a heavily-spined protrusion, a small group of spines at the outer distal angle; third segment broadly ovate, heavily spined along distal margin, a pair of long simple spines at about two-thirds of distance along outer margin.

Gnathopod 1—Subchela. Segment 1 subtriangular, margin slightly curved, lower posterior margin furnished with short spines. Segment 2 elongate, somewhat constricted proximally, length about three and one half times maximum breadth; mid-posterior surface bearing two short simple spines, a single short spine at the postero-distal angle. Segment 3 slightly longer than broad, subrectangular in shape, a cluster of short spines at the postero-distal angle. Segment 4 slightly longer than segment 3, posterior surface elongate, convex and sparsely

spined, bearing a prominent rounded projection a little more than half way along its length. Segment 5 about one and one half times the length of segment 4, posterior surface expanded considerably, a cluster of short simple spines at the antero-distal angle. Segment 6 shorter than segment 5, widening distally. Finger matching the transverse palm, but not covering the produced part of the distal surface of palm. Segment 6 liberally spined on all surfaces.

Gnathopod 2—Subchelate, larger than gnathopod 1. Segment 1 sub-circular, fringed with short simple spines. Segment 2 longer than segment 1, subtrapezoidal, spined along posterior margin. Segment 3 about one quarter of length of segment 2 and half as wide, the anterior distal angle produced to form a rounded projection. Segment 4 subrectangular, as long as segment 3, but slightly narrower, a short simple spine in the postero-distal angle. Segment 5 small, subtriangular. Segment 6 large, nearly as long as segment 2 and twice as wide, broadly ovate; palm oblique, slightly convex, profusely spined. Segment 7, well developed, slightly curved, not extending beyond palm of segment 6.

Peraeopod 1—Segment 1 quadrate, lightly spined along margins. Segment 2 elongate, subrectangular, lightly spined on both anterior and posterior margins. Segment 3 about one-sixth length of segment 2. Segment 4, elongate, spined on both anterior and posterior surfaces. Segment 5 about two-thirds length of segment 4, similarly spined. Segment 6 as long as segment 5 but narrower and more heavily spined. Segment 7 short and curved.

Peraeopod 2—About the same length as peraeopod 1, very similar in structure.

Peraeopod 3—A little longer than peraeopod 2. Segment 1 bilobed. Segment 2 greatly expanded posteriorly. Segment 3 small with a single stout spine at the antero-distal angle. Segment 4 more than twice as long as segment 3, greatly produced at the postero-distal angle, spined on anterior and posterior surfaces. Segment 5 shorter and narrower than segment 4, with clusters of stout spines along anterior surface, and a couple of stout spines at the postero-distal angle. Segment 6 as long as segment 5, but only half as wide, clusters of spines along both anterior and posterior surfaces. Segment 7 well developed and sharply pointed.

Peraeopod 4—Longer than peraeopod 3; similar in structure to peraeopod 3 except for segment 1 which consists of a single lobe.

Peraeopod 5—The longest (mean for 20 specimens 4.6 mm; S.D. = 1.1). Segment 1 ovate, smaller than that of peraeopod 4. Otherwise peraeopod 5 of similar structure to peraeopod 4, although segment 2 is not as greatly expanded as in peraeopods 3 and 4.

Pleopods—All alike, biramous, rami similar and longer than peduncle; inner ramus somewhat shorter than outer.

Uropod 1—Rami subequal in length, about two-thirds length of peduncle, bearing several stout spines apically and spined along outer margins, each ramus two-segmented, the distal segment being a small spine-like structure. Peduncle about six times as long as broad and lightly spined along both margins.

Uropod 2—Much shorter than uropod 1 and stouter in structure. Rami two-segmented as in uropod 1; the outer ramus slightly longer than the inner. Peduncle about as long as outer ramus, but twice as broad. Peduncles and rami equipped with a few heavy spines.

Uropod 3—Uniramous and the shortest of the three. Rami one-segmented, about two-thirds length of peduncle and much narrower, topped with a few spines.

Peduncle broadly expanded, spined along outer margin.

Telson—Triangular in shape; thick, fleshy and deeply cleft; equipped with substantial spines at apex.

Branchiostegites—Simple sac-like structures.

DESCRIPTION OF FEMALE: Maximum body length recorded, 11.5 mm; smaller than males of corresponding age.

Gnathopod 1—Subchela. Segment 6 widening distally to transverse palm as in male.

Gnathopod 2—Chela in female, shorter and more slender than in male. Segment 1 as in male. Segment 2 the longest, broadly convex on anterior surface, lightly spined on both anterior and posterior surfaces. Segment 3 subrectangular, about one-third of length of segment 2, and a little more than half its maximum breadth, produced slightly at the antero-distal angle. Segment 4 shorter and narrower than segment 3, the postero-distal angle broadly rounded and lightly spined. Segment 5 about as long as segment 3 and 4 together, the posterior surface greatly produced. Segment 6 produced at the postero-distal angle, a cluster of spines at the antero-distal angle; palm oblique, well furnished with spines. Segment 7 forming a short curved pointed finger which articulates with segment 6 to form a chela appendage.

COLOUR: The animals are a light reddish-brown in colour in life, and lack any characteristic pigment markings.

TYPES: *Locality*—The holotype is a male specimen from a collection made on the rocky beach at Hastings on Western Port Bay in May 1963. The animals were found in the damp sand under stones in the inter-tidal zone.

Repository—The holotype (No. J. 160) and paratypes (No. J. 161) are lodged at the National Museum of Victoria, Melbourne, Australia.

VARIATION IN MATERIAL EXAMINED: Twenty specimens were examined, half of them being males. They varied in body length from 13.0 mm to 6.0 mm with a mean of 8.8 mm (S.D. = 1.7). Greatest variation occurred in the length of the second antenna which showed a standard deviation of 1.1 with a mean length of 3.4 mm and in the second and third uropods, the latter of which showed a standard deviation of 0.2 for a mean length of 0.5 mm.

DISTRIBUTION: Present Records—VICTORIA: *Lake King* (May, 1956). *Port Phillip Bay*: Altona (May 1963)—Fine sand; thick weed on beach; Canadian Bay (September 1963)—Rocks and coarse sand; Dromana (September 1963)—Sandy beach; very little weed; Kirk Point (April 1963)—Shelly beach; thick weed on beach; Mornington (September 1963)—Rocks; little sand or weed; Point Henry (April 1963)—Coarse sand; little weed; Port Arlington (April 1963)—Sandy beach; little weed; Queenscliff (April 1963)—Coarse sand; little weed; St. Leonard's (April 1963)—Coarse sand; weed scarce; Werribee (May 1963)—Rocky cliff face; no weed; stray wave action. *Western Port Bay*: Corinella (September 1962)—Rocky foreshore; little weed; Hastings (May 1963)—Muddy foreshore; weed piled on beach; Lang Lang (September 1962)—Muddy foreshore; no weed; Point Leo (May 1963)—Fine sand and pebbles; some small rocks; San Remo (September 1962)—Sandy beach; no weed.

ECOLOGICAL NOTES: The species was recorded in a great variety of habitats ranging from the marine waters of Port Phillip and Western Port Bays to terrestrial conditions, as with the type specimens which were collected from damp seaweed on the sandy beach at Hastings on Western Port Bay. The animal was also

collected from the euryhaline waters of Lake King in Gippsland where it was observed burrowing in the submerged sand.

The ubiquitous Talitrids are to be found on almost all coasts, chiefly between tide marks or not far above or below them. Moreover, these forms sometimes reach to considerable altitudes; e.g. *Talitrus sylvaticus* has been observed on Mount Kosciuszko, New South Wales, Australia, and on Mount Wellington in Tasmania, Australia, while others have been found at considerable depths in lakes (Stebbing, 1906). The family has also been recorded by Nicholls (1938) in the waters of the Antarctic region.

Hale (1929) describes the ubiquitous nature of the family in the following terms—'This is, of all the Amphipoda, the family which has made the strongest effort to place itself in evidence and to overcome the disregard of a neglectful world. More than any of the tribe it has invaded the land, so that its representatives may be found, not only in the sand-hillocks above high water mark, but in gardens, in woods far from the sea, on hills, and in craters of extinct volcanoes. It has climbed higher than any of the Crustacea except a few wood-lice, some of the fresh-water forms having been taken at a height of more than thirteen thousand feet in the Great Andes.'

Four Talitrid genera were recorded in Australian waters by Hale (1929), viz. *Talitrus*, *Talorchestia*, *Orchestia* and *Chiltonia*. Species of these forms occur on the sea shore, on land in damp conditions, and in fresh water. *Orchestia marmorata*, the Large Sand-hopper, for example, occurs under sea weed between tide marks on Tasmanian and South Australian beaches, while *Chiltonia subtenuis* is a species which is very prevalent in the South Australian regions of the Murray River.

ANATOMICAL STATISTICS OF *Orchestia Australis* (n. sp.)

Characteristic	Maximum (mm)	Minimum (mm)	Mean (mm)	Standard Deviation	Length of appendage/body length ratio
Body length (Rostrum to telson)	13.0	6.0	8.8	1.7	—
Antenna 1	2.0	0.5	1.0	0.4	0.1
" 2	6.5	2.0	3.4	1.1	0.4
Gnathopod 1	3.5	1.8	2.4	0.5	0.3
" 2 ♂	5.5	2.8	3.9	0.8	0.4
" 2 ♀	3.5	2.3	2.8	0.5	0.2
Peracopod 1	4.0	2.0	3.1	0.5	0.3
" 2	4.3	2.0	3.0	0.6	0.3
" 3	4.8	1.8	3.3	0.6	0.4
" 4	5.5	2.5	3.9	0.9	0.4
" 5	7.0	3.0	4.6	1.1	0.5
Uropod 1	2.5	1.0	1.7	0.4	0.1
" 2	2.0	0.75	1.0	0.3	0.1
" 3	1.0	0.25	0.5	0.2	0.1
Pleopod 1	3.5	1.75	2.4	0.5	0.3

Family OEDICEROTIDAE

Exoediceros fossor (Stimpson), 1855

BRIEF DESCRIPTION: This species is distinguished by the following features: The first antennae have peduncular segments which are successively shorter, and the accessory flagellum consists of a blunt segment tipped with long setae. The second gnathopod is larger than, but similar to, the first with the fifth segment

distally widened and setose. Peraeopods 1 and 2 lack fingers, peraeopods 3, 4 and 5 have the second segment oval and quite setose, and peraeopod 5 is elongate and greatly expanded. The eyes are well developed and variable in position.

VARIATION IN MATERIAL EXAMINED: Twelve specimens of *Exoediceros fossor* were examined, 5 of which were males. They varied in length from 8.0 mm to 4.0 mm with a mean of 5.6 mm (S.D. = 1.3). The greatest variation occurred in the length of the fifth peraeopod which displayed a mean length of 3.8 mm (S.D. = 1.0).

DISTRIBUTION: Previous Records—SOUTH AUSTRALIA: *St. Vincent's Gulf* (Haswell, 1882); *Spencer Gulf* (Sheard, 1937). NEW SOUTH WALES: *Port Jackson* (Haswell, 1882; Whitelegge, 1889; Stebbing, 1906).

Present Records—VICTORIA: *Anderson's Inlet* (May, 1963)—Fine sand; little weed; *Lake King* (October, 1956)—Fine and coarse sand; *Lake Tyers* (May, 1964)—Fine sand; no weed. *Port Phillip Bay*—Beaumaris (May, 1963)—Rocky; green algae abundant; Canadian Bay (May 1963)—Rocks and coarse sand; Dromana (May, 1963)—Sandy beach; little weed; Mordialloc (May, 1963)—Medium to fine sand; Rye (May, 1963)—Sandy beach; little weed; Sorrento (May, 1963)—Sandy beach; little weed. *Western Port Bay*—Hastings (May, 1963)—Muddy foreshore; weed piled up; San Remo (May 1963)—Sandy beach; no weed; Shoreham (May 1963)—Sandy beach; some weed; Summerland (May 1963)—Very rocky; weed in rock pools.

ECOLOGICAL NOTES: *Exoediceros fossor* has been found in a wide variety of habitats ranging from the euryhaline sandy conditions of Lake King to the marine rocky conditions of Summerland, Western Port Bay. The animal has been observed burrowing in fine sands such as those of San Remo, Western Port Bay and Lake King, and in coarser sands such as those of Anderson's Inlet and Canadian Bay, Port Phillip. In Lake King, *Exoediceros fossor* was found in areas devoid of weed. The recorded temperature range was from 9°C to 22°C, and the chlorinity tolerance ranges from 15.8‰ to 9.2‰.

ANATOMICAL STATISTICS OF *Exoediceros fossor*

Characteristic	Maximum (mm)	Minimum (mm)	Mean (mm)	Standard Deviation	Length of appendage/body length ratio
Body length (Rostrum to telson)	8.0	4.0	5.6	1.3	—
Antenna 1	3.5	1.5	2.3	0.7	0.4
" 2	2.25	1.25	1.7	0.4	0.3
Gnathopod 1	2.5	1.25	1.5	0.5	0.3
" 2	3.0	1.75	2.8	0.7	0.5
" 2	2.5	1.25	1.6	0.5	0.3
Peraeopod 1	2.25	1.0	1.5	0.4	0.3
" 2	2.25	1.0	1.5	0.4	0.3
" 3	2.5	1.25	1.9	0.4	0.3
" 4	3.0	1.5	2.3	0.6	0.4
" 5	5.5	2.5	3.8	1.0	0.7
Uropod 1	2.5	1.25	1.7	0.4	0.3
" 2	1.0	0.5	0.8	0.3	0.1
" 3	1.75	0.75	1.1	0.3	0.2
Pleopod 1	2.5	2.5	1.8	0.5	0.3

Stebbing (1906) recorded the presence of *Exoediceros fossor* in Port Jackson burrowing in sand above high water mark. Other members of the family Oedicerotidae, however, have been recorded at considerable depths. Sars (1891), for example, observed *Monoculodes Packardii* (Boeck) at a depth of 100 fathoms, and also *Synchelidium intermedium* in the Trondhjemsfjord at 400 fathoms, together with other deep-water Amphipoda, while Stebbing (1906) recorded the presence of *Paroediceros macrocheir* at depths of up to 900 fathoms in the Arctic Ocean. Nicholls (1914) reported the presence of species of *Oediceroides* and *Methalimedon* in Antarctic waters.

Family COROPHIIDAE

Corophium ascherusicum (Costa, 1857)

BRIEF DESCRIPTION: This species is characterized by having the segments of the urosome fused, with the first uropod inserted in a notch in the lateral margin. In the second antenna in the male, the third peduncular segment bears a large terminal tooth and a smaller one above it. In the first antenna, the flagellum is eight-segmented. The first pair of gnathopods are subchelate, with an oblique tooth on the inner margin of a stout dactyl. The second pair of gnathopods is simple with a stout, tridentate dactyl.

The first uropods are the stoutest and longest, with rami subequal. The second uropods have the inner rami as long as the peduncles, while the outer rami are shorter. In the third uropods, the peduncles are wider than long, with about three setae and a few bristles on the convex outer margins. The rami are ovate, with about 10 slender spinules on the distal margin.

The telson is subtriangular, but the apex is cut off and slightly concave. It is wider than long.

VARIATION IN MATERIAL EXAMINED: Of the 26 specimens examined there was little variability in length evident. The mean length was 3.8 mm with a standard deviation of 0.3. The fifth pereopod is the longest of the appendages, with a mean length of 2.3 mm (S.D. = 0.2).

ANATOMICAL STATISTICS OF *Corophium ascherusicum*

Characteristic	Maximum (mm)	Minimum (mm)	Mean (mm)	Standard Deviation	Length of appendage/body length ratio
Body length (Rostrum to telson)	4.1	3.4	3.8	0.3	—
Antenna 1	1.8	1.6	1.6	0.2	0.4
" 2	1.9	1.5	1.7	0.1	0.4
Gnathopod 1	1.4	1.2	1.1	0.1	0.3
" 2 ♂	2.2	1.8	2.0	0.1	0.5
Pereopod 1	2.0	1.8	1.9	0.1	0.5
" 2	2.0	1.8	1.9	0.1	0.5
" 3	1.2	0.8	1.0	0.1	0.3
" 4	1.9	1.6	1.7	0.1	0.4
" 5	2.5	2.1	2.3	0.2	0.6
Uropod 1	1.0	0.7	0.8	0.1	0.2
" 2	0.4	0.3	0.3	0.1	0.1
" 3	0.3	0.2	0.2	0.1	0.1
Pleopod 1	0.8	0.6	0.7	0.1	0.2

DISTRIBUTION: Present Records—VICTORIA: *Port Phillip*—Hobson's Bay (January 1963)—fine sand; little weed. *Yarra River Estuary* (January 1963)—coarse sand; rocks; little weed.

ECOLOGICAL NOTES: This form obviously has a reasonably great chlorinity tolerance for it was found both in the estuary of the Yarra River and several miles further south in Port Phillip Bay at Beaumaris. (Hobson's Bay).

It was found in both places among green algae attached to rocks, and was not observed to burrow in the sand which, in both environments, was rather coarse.

This lack of burrowing habit is to be expected in the light of the generally slender structure of the peracopods.

This is a ubiquitous species which is commonly found in association with ships, buoys and around wharf structures. Hurley (1954) claimed that the present known distribution of the species traces out some of the major shipping routes, particularly those from England, through the Mediterranean and Suez Canal to South Africa. This is one of the main shipping routes to Australia and New Zealand. The presence of the species in the Yarra River Estuary and around the shores of Hobson's Bay through which Melbourne's shipping routes pass strengthens Hurley's claim.

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- ERRATUM: In Part 1 of this paper [*Proc. Roy. Soc. Vict.*, Vol. 81, Pt. 1: 31-58] *Repository* for holotype and paratypes should read throughout, *National Museum of Victoria, Melbourne*.

AN ATTEMPTED STATISTICAL APPRAISAL OF THE
GRAPTOLITE FAUNA OF WILLEY'S QUARRY,
VICTORIA, AUSTRALIA

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Abstract

This paper aims to show how easily an atypical collection of fossils (in this case Graptolites) can be made from a locality, and explains how early workers could have obtained anomalous relationships between the forms present. It is intended to be a guide to the collector, pointing out that the true relationships of the forms at a locality can be achieved only by (i) collection of sufficient numbers of specimens, (ii) deliberate random collection, (iii) methodical stratigraphic collection without any gaps.

Introduction

A large number of slabs showing graptolites were randomly collected from Willey's Quarry and their fossil content counted to find the relative proportions of the various forms present. Groups of slabs, varying in number, were drawn off at random to determine whether an erroneous result could be obtained by selective or inadequate collecting.

General

Willey's Quarry is a well known graptolite locality about forty miles from Melbourne, approximately one mile W. of the Calder Highway, Lancefield Military Sheet, one in. to the mile, grid reference 580-841. The quarry is situated in rocks of Yappan age and is famous for an abundance and diversity of graptolites.

The area was suggested by Dr. O. P. Singleton, Department of Geology, University of Melbourne, as a suitable locality for a trial statistical evaluation of the number of specimens necessary to indicate accurately the relative percentages of the various components of a fauna. However, the author had for some time been aware of the discrepancies between the percentages given by the early workers for the forms at particular localities and those to be found by casual collecting at these same localities. It was thought that this could perhaps be related to the phenomenon, so common in the Ordovician of Victoria, in which some bedding planes are covered by fossils of almost exclusively one species, while adjoining layers contain a sparser and different population, which may even totally exclude the first dominant species.

Methods

A collection of over 90 fossiliferous slabs was made from the quarry dump, where presumably the full sequence of the quarry had been more or less randomly deposited. Random selection was also practised by digging into the dump and moving from place to place over it. Any slab with a recognizable fossil was

collected, and afterwards the fossil content identified and numbers of each species counted. Only those specimens which consisted of more than half a rhabdosome of a species, or which contained the sicula were counted (see Fig. 1). This eliminated the possibility of counting more than once an individual broken either before or after burial.

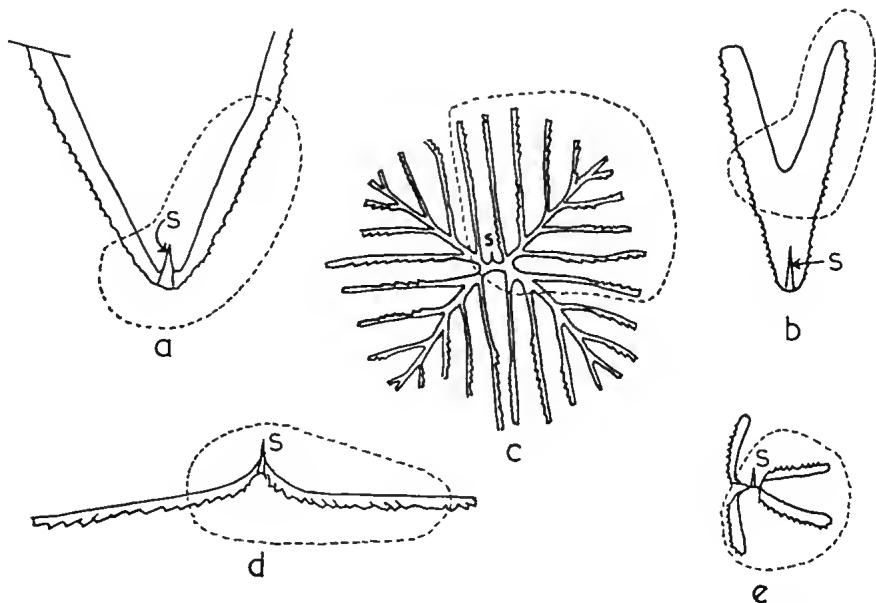


Fig. 1—Shows the portions of graptolite rhabdosomes (within the dotted line) which would be considered sufficient for counting. S indicates the position of the sicula. The figures represent types found at the locality, at about natural size; a, an *Isograptus*, b, *Oncograptus*, c, *Goniograptus*, d, *Didymograptus*, and e, *Tetragraptus*.

The identifications used were those of Harris (1933, pp. 103-104) who tabulated 19 separable species belonging to 11 genera, as well as some unidentifiable forms. The present paper does not claim to substantiate the presence or identification of the species, but merely uses them as forms preferable to an A, B, C, . . . type classification. The descriptions in the same paper were used to separate the various subspecies and here the results with forms like the two subspecies of *Oncograptus upsilon* must be subjective. Some forms were found that could not be referred to any of Harris's listed species, and again some of the forms he identified were not seen, presumably either because of their very small percentage, or because of inadequacies of sampling (see conclusions).

Each slab was numbered and as many graptolites as possible identified on it. When this was done, random (drawn from a hat) brackets of five slabs were made, and the various percentages for each species calculated. The totals of each bracket were consecutively added, and the percentages of the sums to the end of each bracket recorded. In this way it could be seen what percentage of each form appeared in a given number of slabs, i.e. in 20 slabs, 45 slabs, etc., and at what numbers the percentages became statistically stable.

Results and Conclusions

The results were plotted graphically (Fig. 3 shows some typical results) and from these Table I was compiled. In Table I, column (i) shows the number

TABLE I

Forms	(i)	(ii)	(iii)	(iv)	(v)	
	Number of slabs per species	Percentage of all slabs	Number of specimens per species	Percentage of fauna	Minimum percentage	Maximum percentage
<i>Tetragraptus quadribrachiatu</i> s	4	4.2	4	1.3	2.7	1.1
<i>Tetragraptus serra</i>	8	8.4	9	2.9	5.5	0.9
<i>Phyllograptus nobilis</i>	13	4	15	4.9	17	4.0
<i>Goniograptus speciosus</i>	2	2.1	2	0.6	14	—
<i>Trigonograptus ensiformis</i>	4	4.2	4	1.3	1.4	1.0
<i>Didymograptus v-deflexus</i>	10	11	17	5.5	5.7	1.5
<i>Isograptus caduceus divergens</i>	33	5	70	3	43	—21
<i>Isograptus dumosus</i>	12	3	39	3	13	—3
<i>Isograptus manubriatus</i>	35	7	64	21	39	—15
<i>Skiagraptus gnomonicus</i>	8	8.4	19	6.2	7.4	1.8
<i>Oncograptus upsilon</i>	6	6.3	7	2.3	4.1	1.0
<i>Oncograptus upsilon biangulatus</i>	17	8	47	5	32	—15
<i>Cardiograptus morsus</i>	6	6.3	6	2	2.0	1.3
<i>Maeandrograptus tau</i>	1	1.1	1	0.3	0.4	1.3
<i>Others</i>	1	1.1	1	0.3		

of slabs which contained the various species, and column (ii) these slabs as percentages of the total studied. Column (iii) shows the numbers of the individual species of the fauna, column (iv) the percentage of the total population which consisted of this species, and column (v) the maximum and minimum values obtained during counting. The maximum value is self-evident, the minimum value is the lowest value reached after the first peak (see Fig. 2). Column (iv) shows the percentages calculated from all the specimens collected, and column (v) shows the large discrepancies which could occur with insufficient sampling. Most of the graphs show a fairly rapid tailing-off in variability, and most that the averages calculated, for this number of degrees of freedom, were fairly accurate for a sample of 40 slabs (containing approximately 140 individuals).

A comparison of columns (ii) and (iv) shows another discrepancy. It can be seen that apart from *Didymograptus v-deflexus*, the three isograptid species, *Skiagraptus gnomonicus*, and *Oncograptus biangulatus*, the percentage of slabs which contain a given species is approximately three times the actual percentage of the species in the fauna (what one would expect as the slabs average about three fossils each). But, for the above-mentioned species this ratio is closer to unity and in the case of *Isograptus dumosus* is less than unity. This indicates that these species tend to cluster together rather than to occur as individuals in the usual mixed fauna.

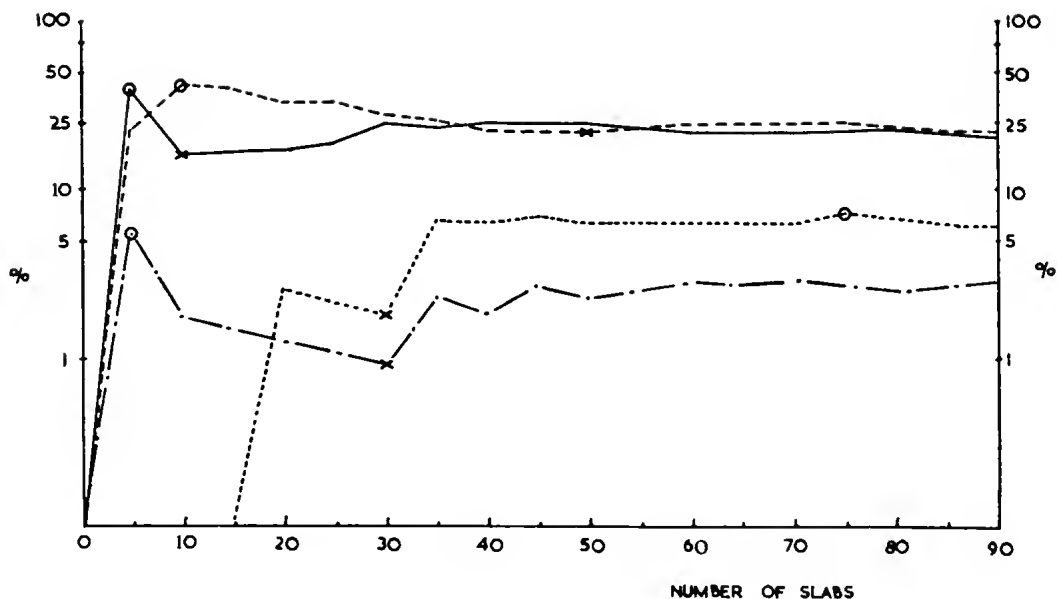


Fig. 2—Shows on semi-log paper, the percentage of the total of four of the forms found, for varying numbers of slabs counted. The percentages are drawn within three logarithmic cycles, 1, 10 and 100. The maximum values are indicated by a circle and the minimum values by a cross. The firm line is for *Isograptus manubriatus*, the dashed line *Isograptus caduceus divergens*, the dotted line *Skiagraptus gnomonicus* and the combined dot and dash represent the values for *Tetragraptus serra*.

Or more quantitatively we can calculate from the natural frequencies a Poisson Distribution and compare the two sets of figures for the various species. The results are similar to those outlined above where most of the species lie fairly close to a Poisson distribution, but for the same five species the curves show pronounced differences from their Poissons. There is a pronounced abundance of slabs (i) without any of the species and (ii) with high counts of the species; thus, the specimens have become grouped together at the expense of the middle values with zero and high counts accentuated. (The goodness of fit of all, or parts of the distributions, can be compared graphically or by the Chi-squared Test. See Appendix for some examples.)

It is this type of block, crowded with specimens not randomly distributed, which catches the eye, and if care is not exercised the collection will certainly not be typical and the population will be biased towards these forms. It is believed that this was the cause of many of the misconceptions of the earlier workers, where populations were estimated as consisting of up to 90% one species.

It is here emphasized that for a true idea of the correct percentage of a species in a population, sufficiently large numbers should be collected and that these should be randomly scattered throughout the section. Should one of these crowded beds be oversampled, by even a small amount, the percentages of a particular form can be markedly increased and should one of these beds be missed, the form, though in fact consisting of a significant percentage, might be overlooked.

Appendix

It can be seen by inspection (from the large frequencies of the lowest class interval), that the distributions would not fit a 'Normal' type distribution; therefore, we must compare them to a Poisson or Binomial distribution. Each of the terms of a Poisson distribution are given by the successive terms of the expansion

$e^{-z} (1 + z + \frac{z^2}{2!} + \frac{z^3}{3!} + \frac{z^4}{4!} + \dots)$ where z is the expectation for the natural values. Having calculated the terms of the expansion, we can now compare the difference, or better still, the difference squared, divided by the expected (Poisson) value, to see how closely they fit (see Table II). It can be seen that the smallest differences lie in the middle ranges, indicating that the extremes are of much worse fit. We can be more quantitative by working out the Chi-square value for

TABLE II
Class Interval

	0	1	2	3	4	5	6	7	8	9	10	11	12
Natural Frequency	3	2	6	2	1	1	0	1	1	0	1	0	1
Poisson Frequency	0.4	1.6	3.0	3.7	3.4	2.5	1.5	0.8	0.4	0.1	0	0	0
$\frac{\text{Difference Squared}}{\text{Expected Value}}$	17	0	3	0.8	1.7	0.9	1.5	0	5				

$$z = 66/18 = 3.67$$

$$e^{-z} = 0.0247.$$

the curves or parts of them. This is given as the sum of the differences squared divided by the expected value of each term, remembering to group when necessary (see Table II); knowing the number of degrees of freedom involved, this value can be converted to a percentage level of fit. We find that the Chi-square value for the full range is 30, giving a fit well below the 0.1% level. The value in the range 1 to 7 gives 7.9 a 40% level fit, in the range 3 to 7 a 50% fit, etc.

Acknowledgements

The author wishes to thank Dr F. C. Beavis and Mr N. Schleiger for assistance with the manuscript, and especially the latter for help with the mathematical approach. He also thanks the University of Melbourne for paying part of the cost of publication of this paper.

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MINERAL SPRINGS OF THE DAYLESFORD DISTRICT

By R. J. W. McLAUGHLIN and JENNIFER J. MACUMBER

Geology Department, University of Melbourne

Abstract

Mineral springs in the Daylesford region and several from other areas have been analysed for Na, K, Li, Ca, Mg, Fe, Mn, B, CO₃, SiO₂, PO₄, SO₄, Cl, Br, and traces of several other minor elements have been detected. The ratios of the major cations are similar to those of normal river and surface waters. This evidence, as well as the low values for silica and boron, indicates an origin from percolating meteoric waters, with no contribution from volcanic fumaroles despite the close association with basalt.

Introduction

The origin of the highly carbonated spring waters in and about the Daylesford region has interested various workers (Newbery, 1867; Skeats, 1914; Whitelaw & Baragwanath, 1923). While the general opinion has been that these spring waters are due to upward movement of ground water along fissures, the frequent association of springs with late Tertiary basalt has raised the possibility of some contribution from volcanic activity. Because of chemical differences which might be expected if this latter were true, various elements have been determined. Analytical methods used were: Calcium and magnesium, E.D.T.A. (Welcher, 1958); sodium and potassium, flame photometry (Vogel, 1961); iron, silica, phosphate, colorimetry (Mullin & Riley, 1955; Shapiro & Brannock, 1962); lithium, manganese and other trace cations, atomic absorption spectroscopy (Willis, 1963); chloride, bromide, carbonate, various titrimetric procedures (Wilson & Wilson, 1962); sulphate, turbidimetry (Vogel, 1961).

The samples were collected as follows: Nos. 1-7, 10 November, 1964; Nos. 8-22, 3 January, 1965. The various elements were estimated as rapidly as possible. Waters were not filtered, since this caused loss of carbon dioxide and precipitation of hydrated R₂O₃. Samples were taken after standing 24 hours to permit settling. After initial determination of chloride, bromide, boron (as borate) and carbonate, the waters were acidified with hydrochloric acid to prevent precipitation, and the remaining constituents then determined. Localities sampled have been shown in Fig. 1 and listed in Table 1.

Results

Concentration in parts per million for fourteen elements has been given in Table 1. Variability has not been investigated in detail, but some indication has been given in Table 2 for several springs which have been sampled at different times during a four year period. The deviation is surprisingly small, considering the variability of the Ordovician shales and sandstones through which the springs rise.

The practice of reporting the various salts as a percentage of a dry weight has not been used in this investigation because of the excess carbon dioxide. Although in the table the carbonate content is given as CO₃, there will be a variety of species, CO₃²⁻, HCO₃⁻ and CO₂. The major cations are calcium, magnesium and

Element	1	4	5	6	7	8	9	12	13	14	15	16	17	18	19	20	21	22
Na	150	435	445	150	200	310	195	360	140	280	295	250	87.5	225	520	425	460	490
Ca	68	130	152	54	92	141	154	97	166	201	83	140	85	194	252	177	168	135
Mg	62	114	122	112	145	144	126	93	148	174	87	124	96	189	235	207	274	406
K	37	126	137	23	68	10	7	18	5	12	10	7	6	7	11	7	8	18
Li	0.1	0.5	0.2	0.1	0.2	0.5	0.2	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.3	0.2	0.4	0.01
Fe	15	5	6	23	9	8	15	7	8	9	6	9	9	7	13	8	9	5
Mn	0.5	0.3	0.3	0.3	0.1	0.2	0.5	0.1	0.3	0.1	0.1	0.2	0.2	0.3	0.5	0.3	0.3	0.2
CO ₃	363	893	935	389	622	855	658	802	725	1070	679	775	422	832	1298	919	943	1256
SO ₄	13	8	8	6	6	26	54	5	6	7	5	8	14	7	57	143	167	46
Cl	43	67	23	123	75	48	63	38	20	20	35	42	30	175	255	306	443	503
Br	0.6	0.2	0.3	0.4	0.2	0.3	0.4	0.2	0.4	0.4	0.6	0.4	0.6	0.4	1.1	1.2	1.3	2.8
B	0.4	0.7	0.7	0.6	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.1	0.1	0.2	T	0.2	0.2
SiO ₂	44	59	38	46	56	47	54	23	54	43	17	47	54	48	44	40	43	52
PO ₄	2.6	<1	<1	1.7	2.0	2.3	2.0	<1	<1	<1	1.2	1.2	2.6	1.5	2.0	2.3	<1	2.0
pH	6.0	6.2	6.2	6.0	6.2	6.3	6.1	6.4	6.2	6.3	6.3	6.2	6.0	6.2	6.5	6.2	6.3	6.5
Na/100	54	64	62	48	46	52	41	65	31	43	63	49	32	37	52	52	51	48
Na+Ca+Mg	24	19	21	17	21	24	32	18	37	31	18	27	32	32	25	22	19	13
Ca/100	22	17	17	35	33	24	27	17	32	26	19	24	36	31	23	26	30	39
Mg/100	3.2	8.3	2.9	21	12	1.8	1.2	7.6	3.3	2.9	7.0	5.3	2.1	25	4.5	2.1	2.7	11
Na+Ca+Mg	Cl/SO ₄																	
Cl/Br.	71	340	78	308	380	160	158	190	50	50	58	105	50	438	232	255	342	180
Na/Cl.	3.5	6.5	19	1.2	2.7	6.5	3.1	9.5	7	14	8.4	6	2.9	1.3	2	1.4	1	1

TABLE 1—Analyses of Carbonated Spring Waters

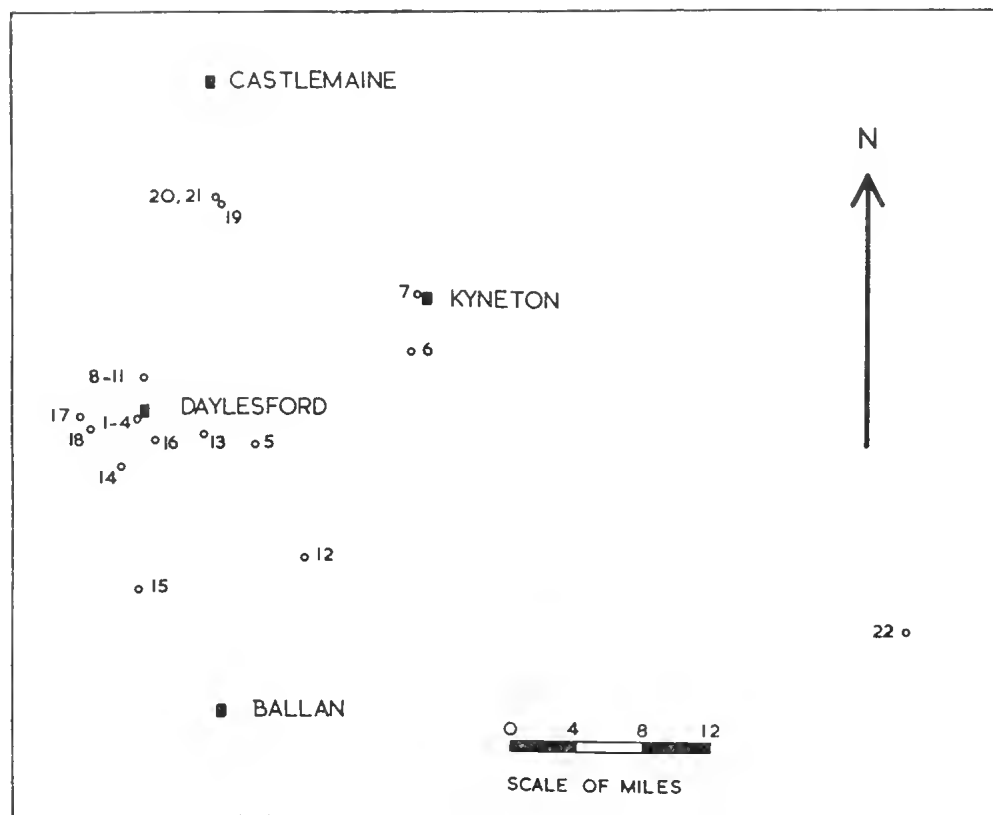


FIG. 1—Localities of carbonated spring waters with analyses Table 1.

sodium. These three, when recalculated to 100%, may be expressed on a ternary diagram, thus enabling various spring waters to be compared, for the other cations are quantitatively insignificant when compared with these three major components. A similar device is not possible for the anions because of the high carbonation.

Discussion

There is no obvious relationship between carbonate content and either the major cations or anions. The inference is that the carbonation of these waters is a totally separate process from the addition of these other ions. Carbonate content affects the pH only slightly, but free evolution of carbon dioxide is sufficient to cause a rise of 0.2-0.3 pH units in twelve hours. This increase is partially responsible for the deposition of hydrated iron oxides from the waters, on standing. The full mechanism of precipitation is not as obvious as it would seem, for it still occurs in sealed containers. The cause is not biological, for waters which have been treated with biological depressants still precipitate. It seems that a photochemical reaction is involved for deposition is more rapid in light.

The other major anions, chloride and sulphate, appear slightly inter-related with ratios Cl/SO_4 ranging generally from under 2 to over 4 and hence are similar to those in rain and river waters. Samples with very high ratios frequently have higher sodium content, and the Na/Cl ratio in these is considerably lower

than in most other samples. This would indicate that the take up of sodium chloride is separate, in at least some samples, from the supply of sulphate. This cannot imply addition of sodium chloride from evaporite minerals or connate water. The solution of halite or similar evaporite minerals gives very high chloride/bromide ratios, since bromide is excluded from the lattices during crystallization (Kuhn, 1955; Stewart, 1963). Bromide contents are very low in all the samples, and for reliable data only those where chloride is above about 60 p.p.m. should be considered. In waters where halides are above about 60 p.p.m. the ratio Cl/Br is similar to that for oceanic, river and rain waters. The conclusion must be reached that there is no contribution to these waters from leached salts. It is suggested that the cause of the high Cl/SO₄ ratio for some samples is not excess chloride but deficit of sulphate resulting from the microbiological activity of sulphate reducing bacteria—*desulphovibrio* sp. (Kuznetsov, et al. 1963).

Boron and phosphate contents are low; the values are normal for underground and river waters. Silica contents are higher than normal river waters, but when the higher total content of dissolved solid is considered, and the influence of chloride on silica solubility (Van Lier et al., 1960), the silica values agree with normal surface and underground waters (White et al. 1963; Livingstone, 1963). The occurrence of traces of zinc and copper in some of the waters is believed to be a result of contamination by material used in the taps or pumps.

The data assembled in Table 1 are strongly against any contribution to these waters from vulcanism, for waters associated with this have quite different chemical compositions. The chloride/bromide ratio is higher (White and Waring, 1963) as also is the boron content; sulphate is higher due to conversion from hydrogen sulphide; silica is higher due to the increased solubility of amorphous silica (Krauskopf, 1956; White et al., 1963). While it might be argued that precipitation en route to the surface might remove certain constituents, e.g. silica, such a precipitate should scavenge much of the iron and manganese from solution and this does not appear to have occurred, for both elements are moderately high and to some extent are interdependent.

The degree of scatter of the points on the ternary diagram in Fig. 2 is very small when it is considered that scatter in closely associated springs (Hepburn 8-11 and Daylesford 1-4) is almost as great. Data from various rivers and streams (Anderson, 1945; Livingstone, 1963) have been plotted on this ternary diagram and the overlap with the field covered by the spring water is quite marked. Perhaps more pertinent still is the data obtained from Wattle Gully Gold mine at Chewton. Water from a spring encountered in drilling at 1600 ft below the surface, when compared with seepage water from about 900 ft depth shows considerable advancement towards the Ca-Mg base in Fig. 2. It is not necessary to appeal to leaching of basalt to provide the additional calcium and magnesium in this case, for the rocks are sedimentary shales and sandstones of Ordovician age, apart from an occasional monchiquite dyke. By analogy, the contribution from leached basalt to the carbonated springs may also be quite small.

The origin of the considerable volume of carbon dioxide in these springs is not difficult to explain. The black Ordovician shales in these areas contain abundant organic material. Oxidation of this material by meteoric water containing oxygen would give carbon dioxide. Oxidation of pyrite would give hydrogen sulphide, which in turn would quite readily give sulphate by the action of thio bacteria. This is a process known to take place extensively (Kuznetsov et al., 1963). Under this hypothesis, carbonated waters should be much more common in the region if the process took place at shallow depths. Since this is not observed, the conclusion

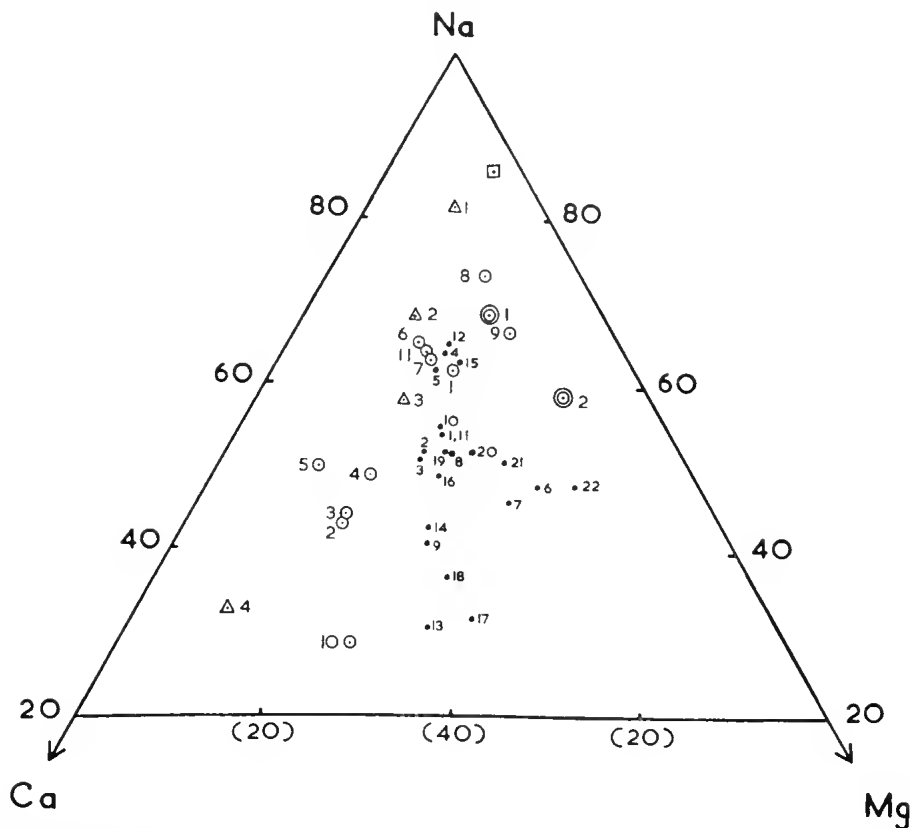


FIG. 2—Portion of the ternary diagram Na, Ca, Mg. Individual samples have been plotted as a percentage of the total Na + Ca + Mg for each analysis.

- average composition of sea water (Goldberg, 1963).
- Δ composition of rain waters: 1 = Bridgewater, 2 = Kyneton, 3 = Charlton, 4 = Merbein. (Values from Hutton & Leslie, 1958).
- ⊙ composition of various river and stream waters: 1 = O'Shannassy, 2 = Hotham, 3 = Kiewa, 4 = Delatite, 5 = Buffalo, 6, 7 = Yarra, 8 = Coleraine, 9 = Little River, 10 = Murray (Tocumwal), 11 = Murray (Murray Bridge) (Values from Anderson, 1941, 1945).
- ◎ Wattle Gully gold mine, Chewton: 1 = seepage at 900', 2 = spring at 1600'.
- = carbonated springs with localities as in Fig. 1 and Table 1.

must be reached that the carbonated springs represent quite deep-seated sources of water which have come to the surface via faults or crush-zones. Their high carbon dioxide content would be enhanced because of higher solubility at high hydrostatic pressure, and their escape to the surface would be via slow seepage rather than direct vents. The increasing salinity of the waters compared with rain water is explained by the theory of ion filtration via charged clay membranes whereby subterranean waters increase in salinity with depth (Bredehoeft et al., 1963). The movement towards the base of the diagram in Fig. 2 may be taken as a measure of the contribution from material dissolved from the rocks through which any individual spring flows.

TABLE 2
Comparison of carbonated spring waters sampled at intervals

Locality	Ca				Mg			
	1963	1964	1965	1966	1963	1964	1965	1966
Kyneton (7)	165	100	92	97	—	150	145	142
Hepburn (8)	—	—	141	155	131	—	144	133
(9)	175	195	154	171	128	106	126	116
(10)	141	144	141	—	114	107	127	—
(11)	127	136	124	120	91	128	116	99

* The numbers in brackets are those used in Table 1. Values are given in parts per million.

Acknowledgements

We wish to thank the University of Melbourne for payment of part of the cost of publication of this paper.

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1968

LIST OF MEMBERS AND ASSOCIATES

Council regrets that the List of Members and Associates as at May 1, 1968, has been omitted from this number of the Proceedings.

The Secretariat of the Society is transferring the membership list, with addresses, to a computer system, and completing this has proved a lengthy process.

To avoid further delay with publication of Volume 81, Part 2, Council therefore decided to go to press without the membership list, which will be published with the next number, Volume 82, Part 1.

Royal Society of Victoria

REPORT OF THE COUNCIL FOR THE YEAR ENDING 7th MARCH 1968

The Council presents to Members of the Royal Society of Victoria the report of its work and on the various activities of the Society during its 113th year.

During 1967 Council devoted a great deal of time to the major question of the future role of the Royal Society of Victoria. A number of important ideas have arisen and this Annual Report will, it is hoped, give members a more detailed picture of what is taking place.

The Society, which is the State's oldest learned Society, has as its aim the advancement of science. The Council of the Society has recently recast its objectives in more specific terms. In addition to the encouragement of research on our local environment through publication and symposia, the Society aims to promote the integration of findings from the various disciplines of science and to interpret their significance in the life of the community for the benefit of non-scientists in other professions and walks of life; to provide a forum where questions of public importance can be debated; and to create an influential body of opinion on matters of national scientific importance.

For some years our membership and our Council have included representatives of a diverse range of interests, but to achieve the aim of bridging the gap between science and the community we must broaden our base still further.

With these ideas in mind, Council will in the next year be seeking increased membership support. Council is anxious to enlarge the membership and has been preparing a small Information Brochure designed to acquaint readers with the Society.

Council hopes that by increasing the membership, the Society may be placed upon a more stable financial platform. When that stage is reached it should be possible for the Society to give really practical consideration to the proper housing of the Library and other projects.

COUNCIL.—The following Office-bearers and Councillors were elected at the Annual General Meeting on 9th March 1967 (except as noted) and managed the affairs of the Society.

President: Dr P. G. Law.

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Professor P. J. Fensham (elected July)

Resignations of Dr F. C. Beavis, Mr R. T. M. Pescott, Dr D. E. Thomas and Professor J. S. Turner from Council at the end of 1966 were accepted with regret and minutes of appreciation were recorded.

Council met eleven times during the year and attendance was good.

COMMITTEES OF COUNCIL.—The following Committees met during the year: House (2), Publications (1), Programme (3), Development (5). A Membership Committee has been formed and will commence work in 1968.

MEETINGS AND LECTURES.—During the year, ten Ordinary Meetings were held. At seven meetings there were Lectures. The remaining meetings were devoted to the presentation of research papers, a regional symposium and the Soirée.

March 9—'Petroleum Exploration Developments, Bass Strait' by Mr B. M. Hopkins.

April 13—'Magnetic Storms and Auroras' by Professor K. D. Cole.

May 11—'Experiences with a Medical Team in Vietnam' by Mr Hamley Wilson.

June 8—'Problems of Development and Conservation in North Western Australia' by Mr Osmar White.

July 13—Research Papers.

August 10—'South Eastern Sewerage Amplification Scheme' by Mr A. G. Robertson.

September 14—Regional Symposium on East Gippsland.

October 12—'The Astronomical Significance of Stonchenge' by Dr Ray Colton.

November 9—Soirée.

December 14—'New Approaches to Dairy Foods' by Mr L. L. Muller.

Attendance was about 730 people as against 510 the previous year. This support is encouraging and Council trusts the programme for 1968 will prove as interesting.

Council decided that in future only one Ordinary Meeting each year would be devoted to delivery of research papers. In future, acceptance of a paper for publication in the *Proceedings* will not automatically entitle the author to read it before the Society other than by title only.

LIFE MEMBERSHIP *Honoris Causa*.—At the April meeting of the Council of the Society, Captain John King Davis was unanimously elected to Life Membership *honoris causa* for his exceptional service to the Society.

MEMBERSHIP.—For the first time in the Society's history, membership has reached 500. The number of members at the 7th March 1968 was Honorary 2, Life 22, Members 374, Country 15 (this category of membership has been closed)

and Associates 88. During the year 33 new members and associates were elected and 11 resignations accepted.

The Society deeply regrets the loss during the year of the following members:

JOHN KING DAVIS was born in London in 1884 and died in Melbourne on 7 May, 1967. Captain Davis early in this century built a reputation as one of the great navigators of Antarctic history. He first sailed to Antarctica with Shackleton as Chief Officer of the *Nimrod* in 1907. He was appointed master of the *Aurora* and second-in-command of Mawson's Australasian Antarctic Expedition of 1911-14 and during three summers' voyages he explored some 1100 miles of unknown coast. For this the Royal Geographical Society awarded him its Murchison Award. In 1916 Davis sailed again in the *Aurora* to rescue members of Shackleton's Trans-Antarctic Expedition from Ross Island. His final Antarctic voyage was again with Mawson, as master of the *Discovery* during the first voyage of the BANZARE Expedition, 1929-30. From 1920 until 1949 he was Commonwealth Director of Navigation and in 1921 he established a cyclone warning station on Willis Island, remaining on the island himself for six months.

Captain Davis was a foundation member of the Executive Planning Committee of the Australian National Antarctic Research Expeditions and served on this committee from 1947 until 1962. He was made a Commander of the Order of the British Empire in 1964. He published three books on his experiences. He was a member of the Council of the Royal Society of Victoria from 1924 until 1964 and was President in 1945 and 1946. He was made an Honorary Life Member in 1966. Until shortly before his death he still attended meetings. Those that met him regarded him with affection. The philosophy of this great man was simple: 'Be honourable and always seek the truth.'

WILLIAM ALEXANDER OSBORNE, was born in 1873 in Northern Ireland and died in Melbourne on 23 August 1967. He took his medical degree of M.B. B.Ch. at Queen's College in the Royal University of Ireland, and was awarded D.Sc. in physiology under Höfner at Tübingen. He came to the University of Melbourne as Professor of Physiology in 1904, and retired at the end of 1938. He numbered among his students many who distinguished themselves in physiology in their later careers, and besides his heavy teaching duties he took an active part in many organizations inside and outside the University. He was a man of extraordinarily wide interests and accurate knowledge, and his name was well known through the community.

He was a member of the Royal Society from 1910, and a Life Member from 1933 until his death. He was a member of the Council from 1910 till 1952, and was President in 1916 and 1917.

BENJAMIN TINDALE was born in Drouin, Victoria, in 1890, and died at Yarra Junction on 6 July, 1967. He was a Member of the Society from 1951, an Honorary Associate of the National Museum of Victoria, and a Fellow of the Royal Microscopical Society. Mr. Tindale was an expert on Diatomaceae, and determined thousands of diatom specimens for the National Museum, for other organizations, and for private individuals. He left a comprehensive review in manuscript of the diatoms of Australia.

MICHAEL KELLY was born in Mintaro, South Australia in 1905 and died in Melbourne on 5 April 1967. He studied at Adelaide University for the degrees of M.B., B.S., which he obtained in 1928. He took up medical practice at Bunbury, Western Australia, and later moved to Victoria. During the last 20 years of his

life he dealt especially with rheumatic diseases. He was both a keen reader and a prolific writer on a wide range of subjects.

He was a member of the Royal Society of Victoria from 1962 until his death, and was a keen attendant at meetings.

NEIL ANDERSON TUDEHOPE was born in 1914 and died in Canberra on 17 July, 1967. He had his secondary education at Geelong Grammar School and gained his B.Sc. at Melbourne University in chemistry. He had an adventurous life in a wide range of employment, and achieved military distinction in the second A.I.F. He joined the Patent Office in 1957 and became a patent examiner specializing in polymer chemistry. He was a member of the Royal Society of Victoria from 1960 until his death.

LAWS.—During 1967 several amendments to the Society's Laws were adopted. The positions of Immediate Past President and Development Manager were created and the duties of the latter defined. The wording of Law 22 (Subscriptions) was altered to allow Council to determine membership dues and, in exceptional cases, to reduce these.

PROCEEDINGS.—During the year the Society published Volume 80 (Parts 1 and 2) of the *Proceedings*. Twenty-one papers were accepted for publication. Palaeontological and zoological contributions of a descriptive nature predominated. The cost of publishing the *Proceedings* continues to be a problem. The length of papers and the cost of preparing tables and plates are currently being scrutinized with a view to economy.

Volume 80 is the first published with the help of the Assistant Editor, Mrs G. Matthaei, and Council congratulates her on its production.

LIBRARY.—2,478 volumes and parts were added to the library during the year. Most of these are obtained by exchange with 336 Australian and foreign organizations. Requests from research workers for access to material have again increased. This year nearly 500 loans were issued, mostly on an interlibrary basis. Council places on record its gratitude to Mr R. E. Anderson, the Assistant Librarian.

HALL.—Increased use was made of the Hall during 1967. In addition to the Society and the lessee, the Royal College of Obstetricians and Gynaecologists, some twenty other professional bodies held some 296 meetings on the premises. During the year the rental was increased by levying a charge for the use of the Supper Room. Repairs costing \$310 were carried out during the year. Catering facilities continue to be a problem, and the possibility of renovating the kitchen is being considered. During the year the Joint House Committee of the R.C.O.G. and the Society met twice to discuss the Hall and its maintenance.

The Cottage, over 98 years old, is in a bad state of repair. Maintenance costing \$474 was necessary during 1967.

FINANCIAL STATEMENT.—The resignation of Mr L. Adams after eleven years as Hon. Treasurer was accepted with regret at the March meeting. Mr Adams reorganized the finances of the Society in a manner that contributed greatly to the Society's progress.

Over the years finance has been a major problem. The lack of any substantial endowments in the past has forced the Society to operate largely on its small annual revenue. During the year the subscriber's price for the *Proceedings* and the rent of the Hall and facilities were increased. In the near future it will also be necessary

to increase membership subscriptions. The Financial Statement shows increased revenue from subscriptions, sale of publications, rent and hallkeeping refunds. Expenditure also increased generally in response to increased activity. It has been necessary to employ a part-time Clerical Assistant throughout the year and this accounts for most of the increased expenditure in salaries. The main financial burden this year was the carrying over of the cost of Volume 79 (2) of the *Proceedings*: \$6,000 from the previous year.

TREASURER'S REPORT

SUMMARY FOR THE YEAR ENDED 31st DECEMBER 1967

Balance from 1966	\$6,052.43
Total Receipts	14,009.15
	<hr/>
Total Payments	\$20,061.58
	19,072.09
	<hr/>
	\$989.49
Unpresented cheques	74.23
	<hr/>
Balance brought forward as Bank Balance at 31st December 1967	\$1,063.72
	<hr/>

INVESTMENTS HELD AS AT 31st DECEMBER 1967

Australian Newsprint Mills Holdings Ltd.	
7½% Registered Unsecured Notes	\$200.00
Industrial Acceptance Corporation	
7% Registered Unsecured Notes	8,000.00
Finance Corporation of Australia Ltd.	
6½% Registered Unsecured Notes	1,800.00
Ford Motor Company of Australia	
7% Debenture Stock	2,000.00
	<hr/>
	\$12,000.00
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BEQUESTS AND GIFTS.—Council acknowledges with gratitude the following gifts: From Mr M. A. Cuming and Dr Rac Dungan, back numbers of the Society's *Proceedings*. From a member, a donation of \$40. The Society is a beneficiary of the Estate of the late Professor E. W. Skeats, which is currently being executed. Council understands that the Society will receive about \$50,000 from this generous bequest. This bequest will be held as an investment and use made only of the income derived from it.

DONATIONS TOWARDS THE COST OF PUBLISHING THE *PROCEEDINGS*.—Council acknowledges with gratitude the following financial assistance. Government of Victoria, \$1,600.00; University of Melbourne, Publications Fund, \$922.50; Department of Mines, \$70.00.

REPRESENTATION of the SOCIETY.—The President represented the Society on the Natural History Medallion Committee. The President, Dr P. G.

Law, together with Mr E. D. Gill and Dr M. J. Littlejohn were appointed Society delegates to the 40th ANZAAS Conference held in Christchurch, New Zealand.

RESEARCH MEDAL.—No award was made in 1967.

BUREAU OF METEOROLOGY.—The lease to the Bureau of the Melbourne Weather Station site has been renewed for a further five years.

IAN CLUNIES ROSS MEMORIAL FOUNDATION.—Close and friendly association continues between the Society and the Foundation. The Governors of the I.C.R.M.F. kindly accredited the Society to the National Science Centre, thus enabling Royal Society members to apply for membership of the Sciences Club. The Council extend best wishes to the Foundation whose building will open this year.

EXHIBITION.—During November an exhibition of Bausch and Lomb optical and electrical equipment was held in the Society's Hall. The exhibition was organized by Astronic Imports and attracted many professional people to the Hall.

Many people have assisted the Society during the year and Council, on behalf of the Society, wishes in particular to thank the following individuals and organizations: Sir Ian Potter (Hon. Financial Adviser), Mr Roy Grounds and Mr F. Suendermann (Hon. Architects), Phillips, Fox and Masel (Hon. Solicitors), the Parks and Gardens Department of the Melbourne City Council, Miss Jean Colledge, Miss Elaine Spry, Miss Erica Barics, Dr Lance Finch, Mr H. P. Simpson, Sir Samuel Wadham, Mr R. C. Seeger, Dr Andrew Fabinyi, Mr and Mrs A. Sadik, and Mrs F. E. Boyd.

This Annual Report and Financial Statement have been adopted by Council for presentation to the Annual General Meeting on 14th March 1968.

P. G. LAW, *President.*

FINANCIAL STATEMENT FOR YEAR ENDED 31st DECEMBER 1967

RECEIPTS		PAYMENTS	
Balance brought forward as at 1st January 1967 ..	\$6,052.43	Salaries—	\$361.00
Subscriptions ..	3,578.31	Assistant Librarian ..	971.50
Sale of Publications ..	3,172.09	Assistant to Hon. Secretary ..	200.00
Interest—		Assistant Editor ..	1,029.57
Investments ..	\$752.25	Repairs and Maintenance ..	75.75
Benefactions ..	530.00	Rates and Taxes ..	448.79
National Bank of Aust. ..	110.81	Electricity ..	160.80
		Telephone ..	287.29
Grants and Donations—		Postage ..	13,841.26
University of Melbourne ..	\$437.50	Publishing <i>Proceedings</i> , Vols. 79 (2), 80 (1 and 2)	228.77
University of Melbourne ..	485.00	Stationery ..	470.90
State Treasury ..	1,600.00	Expenses of Meetings ..	528.00
A Member ..	40.00	Hallkeeping ..	52.60
Department of Mines ..	70.00	Sundry Expenses ..	197.16
		Insurance ..	3.50
Rent ..	2,685.97	Metropolitan Fire Brigade ..	200.00
Hallkeeping ..	305.05	Investment ..	20.00
Miscellaneous Refunds ..	42.17	Duty Stamps ..	15.00
Sale of Investments (for reinvestment) ..	200.00	Cheques not credited ..	
		Bank Balance at 31st December 1967 ..	\$19,072.09
			1,063.72
		Less Unpresented Cheques ..	\$20,135.81
			74.23
			\$20,061.58

(Signed) JAMES D. MORRISON,
Hon. Treasurer

We have examined the books and records of the Royal Society of Victoria for the year ended 31st December 1967, and in our opinion the Financial Statement is properly drawn up and gives a correct view of the financial transactions of the Society for that year.

(Signed) R. R. GARRAN } Hon.
H. P. SIMPSON } Auditors

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